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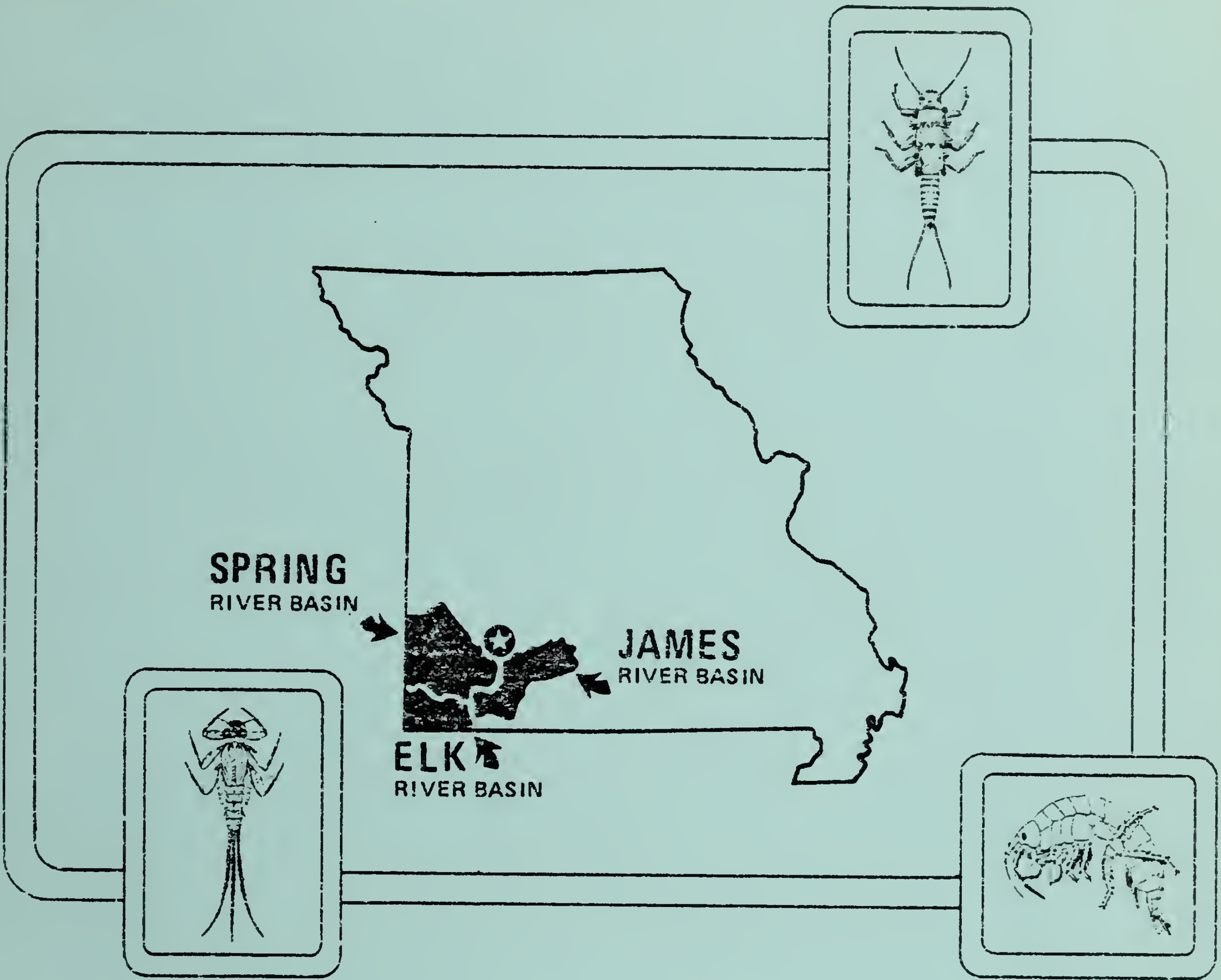

A MACROINVERTEBRATE BIOTIC INDEX

FOR WATER QUALITY IN THE SOUTHWEST MISSOURI OZARKS

Based on Data from the James, Elk, and Spring River Basins

CITY UTILITIES OF SPRINGFIELD, MISSOURI

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A MACROINVERTEBRATE BIOTIC INDEX FOR WATER QUALITY ANALYSIS IN THE SOUTHWEST MISSOURI OZARKS BASED ON DATA FROM THE JAMES, ELK, AND SPRING RIVER SYSTEMS

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ABSTRACT

A biotic index was devised that uses riffle invertebrates to classify stream water quality in southwest Missouri relative to nutrient enrichment. To create this index, the invertebrate fauna was divided into about 85 taxa, each assigned a water quality number to represent its water quality preference. These numbers were assigned based on extensive chemical, bacteriological, and invertebrate data gathered by the Missouri Clean Water Commission from the James, Elk, and Spring River Systems in 1964-65. The biotic index for a given location may range from 0-5, and is simply the average water quality number for all of the individuals in a sample.

The resulting biotic index correlated well with the composite chemical and bacteriological data upon which it was based, and related well to known sources of pollution. Tables are presented that relate the biotic index to water quality.

A BIOTIC INDEX FOR SOUTHWEST MISSOURI

INTRODUCTION

The species composition of an aquatic community is influenced by water quality and will change if water quality changes. In fact, aquatic community structure can be used as a measure of water quality. Such a community, however, commonly includes 30 or 40 taxa in varying numbers, and if communities from several locations or times are to be compared the quantity of data involved can become overwhelming, and its significance relative to water quality difficult to grasp.

One method by which this problem may be overcome is to use a biotic index. The mathematical manipulations used in this technique result in the reduction of a large quantity of data for a given location to a single dimensionless number that reflects water quality when compared to a pre-established scale. This reduction of data simplifies the comparison of data from different locations or times.

The biotic index described in this report is designed to assess organic pollution from sources such as sewage, the dairy industry, livestock, etc., and is intended for use in typical Ozark type streams in southwest Missouri. Its development grew from a desire for a practical method of biological monitoring in the streams that contribute to the public water supply of the City of Springfield, Missouri.

In this system, the invertebrate riffle fauna is broken into about 85 designated taxa, each of which is assigned a water quality number depending on the quality of the water in which it is most typically found. A water quality number of 0 indicates a taxon typical of the best water quality. A number of 5 indicates a taxon typical of the worst water quality. Intermediate numbers indicate taxa typical of intermediate water quality. The biotic index for a given sample is simply the average water quality number of all the individuals in the sample. Using this system, the biotic index for a given sample may range from 0 to 5 and can be interpreted according to table 9.

This biotic index is patterned after one first used by Chutter[1] in South Africa, and later, in slightly altered form, by Hilsenhoff[2] in Wisconsin. The Hilsenhoff version of the method has since been used favorably in Missouri by Jones, et al.[3]

Hilsenhoff's version of the index is the most general and widely applicable in theory because the taxonomic units to which water quality numbers are assigned are individual species. One of the disturbing aspects of using his version, however, is the difficulty in finding keys with which to identify species, or otherwise developing enough skill to make correct identifications, i.e. for many taxa, confident identification to species

lies primarily with people specializing in that group of organisms, and for a number of aquatic taxa, identification beyond genus is not possible because formal descriptions of species are still lacking, or keys are simply not available. In addition, water quality numbers have yet to be assigned to species for many areas, and the water quality number appropriate for a given species may vary from area to area depending on what subspecies is prevalent there.[4] In addition, if it happens that identification can be done with confidence to genus only, the water quality number of the most pollution tolerant species in that genus is assigned, so depending on the level to which a biologist identifies a specimen, its water quality number may change. Given such a system, identification can become extremely laborious and exceptionally time consuming.

To develop a biotic index for Southwest Missouri that would not vary depending on the area of specialization of the biologist, or the availability of identification keys, a standardized data sheet containing a standardized group of the most common taxa in southwest Missouri was developed with which to calculate the biotic index. The levels of identification required to complete the data sheet are possible using commonly available identification keys.[4-7]

ASSIGNMENT OF WATER QUALITY NUMBERS TO THE TAXA

The development of this biotic index is based on the extensive benthic invertebrate, chemical, and bacteriological data collected from the James, Elk, and Spring River systems by the Missouri Clean Water Commission (Missouri Water Pollution Board) in 1964 and 1965.[8-10] During that time they collected one sample during each season from 52 different locations. For this index, data from 42 of these locations were used. At them, water quality varied from good at some locations to severely polluted at others. We did not use data from the other ten locations because five of them were plains locations having more turbidity and less relief than typical of Ozark streams, and the other five were strongly influenced by a chemical manufacturing plant that discharged effluent with high ammonia content, low pH, and not the organic type pollution to which we were limiting our analysis.

Using these data, we were able to assign water quality numbers to all of the invertebrate taxa except oligochaetes and chironomids (explained on page 5) by observing the kind of water in which the taxa were most characteristic. In order to do this, the kinds of water at the 42 locations were categorized by ranking the locations according to their water quality based on 11 chemical and bacteriological parameters indicative of organic pollution. These parameters included percent dissolved oxygen saturation, specific conductivity, nitrite - N, nitrate - N, ammonia - N, orthophosphate, detergent as ABS, coliform bacteria, fecal

streptococcus bacteria, turbidity, and chloride. Of the four seasonal samples, the worst case for each parameter was used to rank a location for that parameter. Worst case conditions were used under the assumption that contamination does not necessarily enter a stream on a regular schedule with regard to either quality or volume, and that a stream's worst condition is most likely to limit which invertebrates are likely to thrive there.

Having ranked each location from best to worst (from 1 to 42) for each of the eleven parameters, the eleven ranks for each station were then averaged to give a single average water quality rank. Given these average ranks, the locations were arranged from best to worst water quality. The seven locations having the best water quality were given a water quality number of "0" to indicate little or no organic pollution. The worst seven were given a water quality number of "5" to indicate the worst organic pollution. The intermediate groups of seven were given water quality numbers from "1" to "4" to reflect their relative degrees of pollution. These water quality numbers were then assigned to invertebrate taxa by comparing the distribution of each individual taxon to the distribution of water quality.

This comparison of distributions was done by listing the locations in ranked order according to water quality and then listing the number of individuals for each taxon under its corresponding location, table 1. If the greatest concentration of a taxon occurred at locations with water quality numbers of 0, that taxon would be assigned a water quality number of 0. If a taxon was equally distributed at stations spanning several water quality numbers, say 2-4, the taxon would be assigned a water quality number of 3. If a taxon was common at stations with water quality numbers from 1-4, but had an apparent center of distribution corresponding to locations with water quality numbers of 2, the taxon would be given a water quality number of 2. Occasionally, if the center of distribution seemed to fall on a line, between whole number designations, the taxon was given a water quality number such as 2.5. These numbers were assigned visually, and were not calculated mathematically, so the results are somewhat subjective, but in this way, all of the approximately 320 taxa identified in the Clean Water Commission study were given water quality numbers, several examples of which are shown in table 1.

These 320 taxa were then lumped into the approximately 85 taxa listed on the standardized data sheet, table 2. The water quality numbers of these lumped taxa were assigned based on a rough average of the water quality numbers of the taxa of which they were composed.

COMPLETING THE BIOTIC INDEX DATA SHEET

The standardized data sheet used to calculate this biotic index is shown in table 2. On this sheet the assigned water quality numbers are given next to each designated taxon (except for oligochaetes and chironomids, to be explained later). The first step in filling out this data sheet is to have an invertebrate sample.

Collecting the Invertebrate Sample

The Clean Water Commission samples upon which this index is based were collected from 12 square feet of riffle bottom if the stream was wider than 25 feet, or from 6 square feet if stream width was less than 25 feet. They used a net with 20 meshes to the inch, allowing the organisms to be swept into it by the current while digging the required number of square feet with a three-pronged cultivator. Large substrate was hand picked to assure removal of organisms that remained attached. Since the biotic index does not depend on quantitative sampling, exact sampling technique is probably not important, but an effort should be made to sample enough of the riffle to get a representative sample.

Hilsenhoff[2] concluded that a sample of about 100 individuals is adequate for calculating the biotic index, so controlling sampling to limit the number of invertebrates collected is one method to streamline sampling, counting, and identification. If a sample does contain a very large number of invertebrates, it is acceptable to reduce its size by drawing a subsample from it, taking care that the subsample is representative: if alive, be careful not to select a disproportionate number of the larger active species, and if preserved, be sure the sample is uniformly mixed and beware of clumping that tends to occur for some taxa.[11] Because of the method used for assigning water quality numbers to oligochaetes and chironomids (discussed later) it is not recommended to collect fewer than 100 individuals when using this index. (Of the 168 samples collected by the Missouri Clean Water Commission, only six contained fewer than 100 invertebrates, table 3. Although these do not represent ideal samples, they were but a small proportion of the total collected and were included with the others for analysis in this report).

Identification Of Invertebrates

After collection, the invertebrates must be identified, counted, and recorded on the data sheet. The data sheet gives the required level of identification. Only the Stenonema mayflies are identified beyond genus, being separated into two groups: the Femoratum group having rounded gills, and the Pulchellum group having truncated gills.

Inspection of the data sheet shows that most taxa are identified to genus, but a few are identified to less specific levels such as family or order. Those taxa not definitely named on the data sheet should be recorded in one of the "others" categories at the designated taxonomic level. For instance "other" stoneflies should be generically distinct, while "other" diptera should be separable into families. There is no need to identify specimens in the "others" categories so long as they can be separated at the proper level. For instance, two kinds of dipterans in the "others" category need not be identified to family so long as they can be counted as one family or as two separate families as the case may be.

Of the 168 Clean Water Commission samples used in this analysis, the greatest proportion of individuals in "others" categories was 11%, and was 7% or more only 3 times. For all other samples, the percent "others" was less than this. If a relatively large proportion of a sample were to fall among the "others" categories, this biotic index should be used with caution.

Assigning Water Quality Numbers To Oligochaetes And Chironomids

After identification and counting, water quality numbers must be assigned to oligochaetes and chironomids. These taxa are typically found in large numbers in organically polluted water, but many species within these taxa are also characteristic of clean water where they may also be quite abundant. Therefore, to assign water quality numbers to oligochaetes and chironomids that better represent the span of their water quality preferences than a single number, water quality numbers (ranging from 2 to 5) were assigned to them based on the diversity of the sample population from which they came. Diversity was chosen for this purpose because of the tendency for clean water locations to have a greater diversity of species than polluted water locations. This occurs because as water quality is degraded, fewer species are able to tolerate the degradation.[11]

Diversity in this case was taken to be the number of taxa one might expect in a sample of 100 organisms and the method for determining this is shown in table 4. Using this method, the number of taxa in large samples, such as of 200 or 1600 individuals could be reduced to what would be expected were the sample of only 100 individuals. The method is based on the assumption that any taxon making up at least 1% of a large sample population would have been present if only 100 specimens had been collected, but that only some of the taxa comprising less than 1% of a large sample population would have been present. For the latter group, since each member comprises less than 1% of the sample population, one would not expect any of them to occur more than once in a sample of 100. In a large sample in which, for instance, 6% of the sample were composed of 11 taxa each less than 1% of the total, one might expect only 6 of these to be present in a sample of 100, one for each percentage point. Thus, diversity (taxa/100 organisms) was calculated to be: the number of taxa

each greater than or equal to 1% of the sample population plus the percentage of the population made up of taxa each less than 1% of the total population.

Note that in calculating taxa/100 organisms all of the taxa from the data sheet including each one under "others" were included, but that the uncertain Stenonema were not included unless no other Stenonema were identifiable to group.

Table 5 shows how water quality numbers were assigned to oligochaetes and chironomids depending on the result from table 4. Blank spaces are left on the data sheet next to oligochaetes and chironomids for recording this number.

Calculating The Biotic Index

The biotic index is calculated by multiplying the water quality number of each taxon by the number of organisms in that taxon and entering each product in the last column on the data sheet. The sum of these products is then divided by the total number of individuals in the sample. The result is the biotic index, or the average water quality number for the sample population as a whole.

AN ADJUSTMENT TO THE BIOTIC INDEX

Normally, clean water stations have a rich diversity of species with no one species that dominates population structure. Occasionally, however, some taxa will comprise a disproportionately large part of a population as a natural course of events, and not due to pollution.[11] Such taxa can have a disproportionate effect on the biotic index of clean water stations. To reduce this affect, Hilsenhoff[2] chose not to collect a given genus beyond 25 individuals in his 100 individual samples and to collect for only a given amount of time if 100 individuals could not be found. This concept was applied to the Clean Water Commission data such that any taxon over 25% of the population was reduced to 25% to learn if such an adjustment would improve the correlation between the biotic index and water quality (shown in the next section). The adjustment was made after diversity was calculated and water quality numbers were assigned to oligochaetes and chironomids. Also, the adjustment was made only if diversity was greater than 10 taxa/100 organisms, and then it was only applied to oligochaetes and midges if they made up less than 50% of the population (to conform with the method for assigning their water quality numbers, table 5). If they made up more than 50% of the population, the adjustment was not made unless diversity was greater than 14 taxa/100 organisms. Guidelines that show when taxa were reduced to 25% are given in table 6.

A diversity of 10 taxa/100 organisms was chosen as the cutoff point for reducing a taxon to 25% because it was felt that below this level it would become too likely for a given taxon to exceed 25% due to the reduced diversity, and that a heavy concentration of one taxon (usually oligochaetes, midges, and other relatively pollution tolerant forms) was probably a valid reflection of real water quality.

Table 7 gives the methods by which taxa comprising greater than 25% of a population were adjusted to 25% of it. If this adjustment is made, the appropriate notes should be added to the data sheet, and it should also be reinspected to see that the reduction in population size did not elevate a different taxon to over 25%. If so, this taxon must also be reduced. It should be noted that if this method is employed, more than 100 invertebrates should be collected so the adjusted population will not be reduced to below 100 individuals.

CORRELATIONS BETWEEN THE BIOTIC INDEX AND CHEMICAL-MICROBIOLOGICAL WATER QUALITY

Rank correlations comparing the biotic index to water quality for the 42 locations used in this study are given in table 8. In all cases (for each season and the annual average) the correlations exceeded the .001 level of significance (.481) thus suggesting that water quality numbers were assigned adequately well. Also, the biotic index calculated from adjusted data gives a slightly better correlation in all cases than does the biotic index calculated from unadjusted data, suggesting that the adjustment does improve the index to some extent.

INTERPRETING WATER QUALITY USING THE BIOTIC INDEX

Table 9 suggests how this biotic index may be interpreted, and may be used with either the unadjusted or adjusted biotic indices. For example, a biotic index of 3.11 for a summer sample would indicate moderate pollution, suggesting a potentially critical situation that could lead to trouble. A biotic index of 2.09 would indicate little or no organic pollution was present. The table is identical for all seasons except for the separation between the "little or no pollution" category and "minor pollution" category.

This table was developed from tables 10 and 11 which compare recorded pollution sources for each site with biotic index values. The circles in tables 10 and 11 represent stations with known sources of pollution; the degree to which the circles are darkened reflects the probable magnitude of the pollution. The +'s represent stations with no obvious source of pollution. The circles and +'s are matched with their respective stations in table 12, where a brief description of the nature of recorded pollution is given.

Based on the pattern of circles and +'s, the lines in tables 10 and 11 were drawn to separate the tables into water quality categories. The solid lines were drawn based on the tables as a whole, and the dotted lines show deviations from these for individual columns. Deviation lines were drawn only between the highest two water quality categories.

In general, the "severe pollution" category in tables 10 and 11 contains almost all black circles. The "considerable pollution" category contains primarily half black circles. The "moderate pollution" category contains everything from half black circles to +'s, but its upper limit is based on the upper location of half black circles. The "minor pollution" category contains a mixture of clear circles and +'s. The "little or no pollution" category contains all, or nearly all, +'s. Thus, the water quality categories given in table 9 are established based on the relationship between ranked water quality (the chemical and bacteriological data upon which water quality numbers for the invertebrate taxa are based) and the known existence of pollution at each station.

Although these categories appear relatively distinct, water quality, in reality, varies on a continuum with no clear breaks between polluted and unpolluted water. Nonetheless, such categories help categorize that continuum into meaningful segments for the purpose of interpretation.

Table 13 gives the biotic indices for all of the stations used in this analysis. Figure 1 maps the locations of these stations, and figure 2 maps the distribution of the averaged seasonal adjusted biotic index values. Figure 3 maps the information in figure 2 in terms of the water quality symbols used in table 12.

THE BIOTIC INDEX RELATIVE TO THE CHEMICAL-MICROBIOLOGICAL DATA

Table 14 gives all of the Missouri Clean Water Commission chemical-bacteriological data used in this analysis. Table 15 relates statistics derived from these data to the water quality categories established for interpretation of the biotic index. Although there is a

great deal of overlap in chemical-bacteriological values from one water quality category to the next, figure 4 shows the general relationships based on averaged chemical-bacteriological data.

Figure 4 shows that although a trend is present, the chemical-bacteriological data do not relate directly to the water quality categories. In most cases, the chemical-bacteriological parameters rise only gradually through the three or four best water quality categories, but rise sharply in the worst one. In some cases the trend is irregular. This is most obvious for the fourth water quality category, but only two stations are represented here, so this irregularity could be due, in part, to chance.

Of the parameters used in this study, nitrate nitrogen was the only one that showed no trend relative to the assigned water quality categories. The reason for this is uncertain, but could relate to the many transformations in form that occur ecologically among nitrogen containing molecules. Nitrite and ammonia nitrogen, however, followed the trend nicely. It would appear, then that nitrate nitrogen used alone would be the least reliable predictor of water quality of the parameters used in this study. Total nitrogen would perhaps produce less erratic results.

Some of the irregularities in figure 4 could result from grab samples not coinciding with average stream conditions. This could happen if contamination were transient or periodic in nature, and missed by infrequent grab sampling.

Regardless, a point that must be made is that it is the combination of these pollutants and their synergistic actions within the receiving waters that contribute to overall changes in stream water quality and subsequent changes in faunal composition. Occasional periods of improved water quality will not radically affect the fauna, but increasing periods of degraded water quality will. Faunal composition will tend to adjust to overall water quality, and therefore provide information regarding water quality that might be missed by occasional chemical-bacteriological grab sampling.

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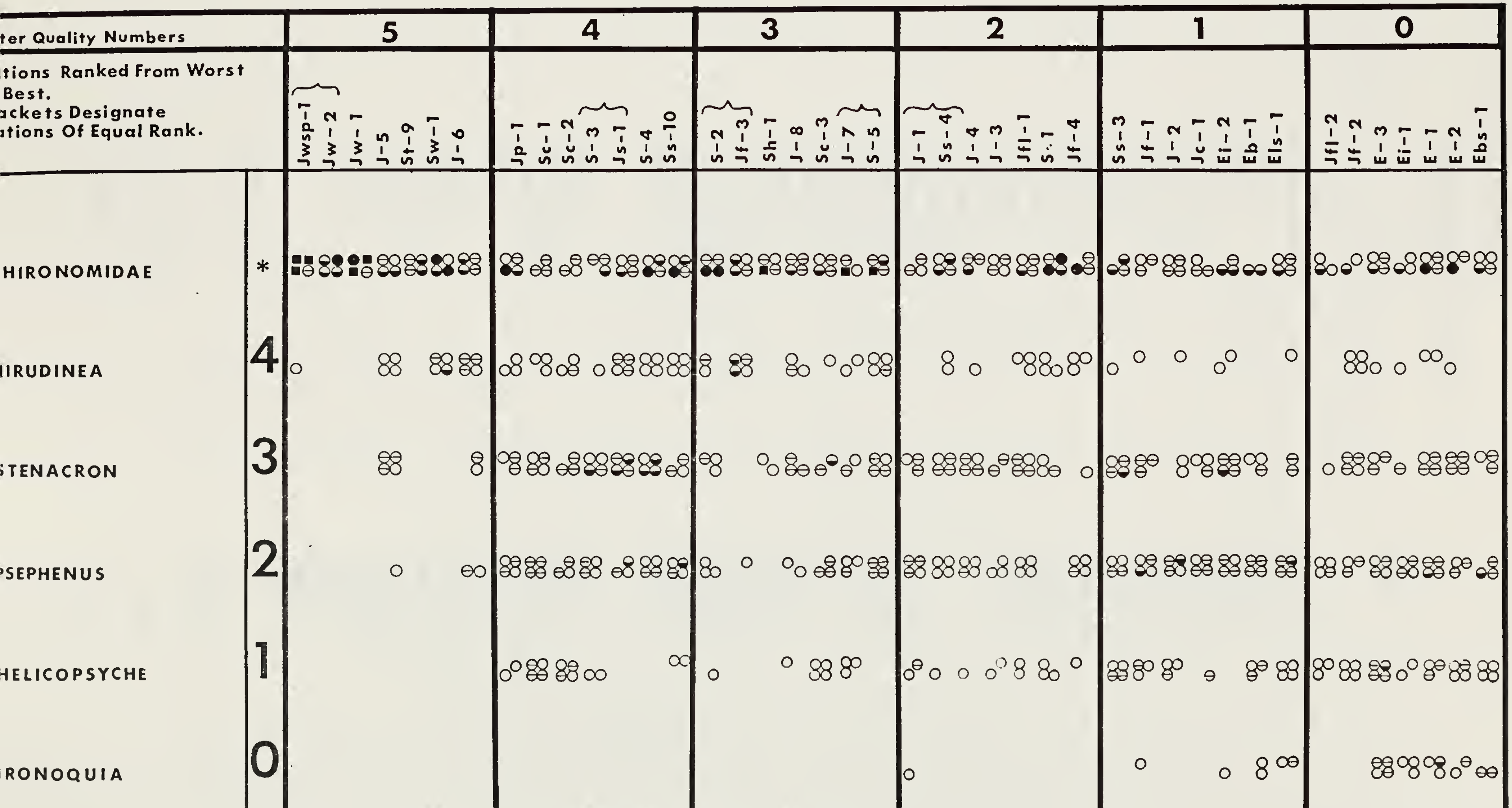
Table 1. Examples to demonstrate the method for assigning water quality numbers to taxa based on their distributions relative to water quality.

LEGEND

- ○ 1-9 Individuals per Sample**
- ⊖ 10-99
- ◒ 100-499
- ● 500-999
- ■ ≥1000



*Water quality number varies from 2-5 depending on diversity, see Table 5 .

** Sample sizes were either 6 or 12 square feet.

Table 2. Standardized Data Sheet for Biotic Index Determination.

MACROINVERTEBRATE BIOTIC INDEX

Stream: ________________________ Date: ____________ Biotic Index: ____________

Station: ________________________

TAXA	VAL	#	VAL * #
WORMS			
Flatworms:	3.5	----	----
Oligochaeta:	----	----	----
Hirudinea:	4	----	----
SNAILS			
Amnicola:	4	----	----
Ferrissia:	3	----	----
Goniobasis:	3	----	----
Physa:	4	----	----
Pleurocera:	3	----	----
*Others:	3	----	----
	3	----	----
	3	----	----
AMPHIPODS			
Crangonyx:	3	----	----
Gammarus:	4	----	----
Hyalella:	3	----	----
Synurella:	3	----	----
*Others:	2	----	----
	2	----	----
ISOPODS			
Asellus:	2	----	----
Lirceus:	2	----	----
*Others:	2	----	----
STONEFLIES			
Acroneuria:	2	----	----
Allocapnia:	2	----	----
Isoperla:	1	----	----
Neoperla:	2	----	----
Neophasganophora:	2	----	----
Perlesta:	2	----	----
Taeniopteryx:	3	----	----
*Others:	2	----	----
	2	----	----
	2	----	----
OTHERS			
		----	----
		----	----
# of Taxa >= 1%		----	
% Org. of Taxa < 1%		----	
Taxa/100 Organisms		----	

TAXA	VAL	#	VAL * #
MAYFLIES			
Baetis:	3	----	----
Caenis:	3	----	----
Centroptilium:	3	----	----
Choroterpes:	2	----	----
Cloeon:	4	----	----
Ephemera:	2	----	----
Ephemerella:	0.5	----	----
Ephoron:	3	----	----
Heptagenia:	2.5	----	----
Hexagenia:	3	----	----
Isonychia:	2	----	----
Leptophlebia:	2	----	----
Paraleptophlebi	1	----	----
Potamanthus:	2	----	----
Pseudocloeon:	2	----	----
Rithrogenia:	0	----	----
Siphlonurus:	2	----	----
Stenacron:	3	----	----
Stenonema:		----	----
Femoratum Gr:	3	----	----
Pulchellum Gr:	2.5	----	----
uncertains:	3	----	----
Tricorythodes:	3	----	----
*Others:	2	----	----
	2	----	----
	2	----	----
ODONATA			
Argia+Coenagrii	2	----	----
Gomphidae:	2	----	----
**Others	2	----	----
	2	----	----
HEMIPTERA	3	----	----
MEGALOPTERA			
Corydalus:	2	----	----
Sialis:	2	----	----
*Others:	2	----	----
	2	----	----
OTHERS			
		----	----
		----	----
% Olig. + Chiron.		----	
% Others		----	

TAXA	VAL	#	VAL * #
CADDISFLIES			
Agapetus:	1	----	----
Agraylea:	3	----	----
Cheumatopsyche:	2.5	----	----
Chimarra:	2	----	----
Glossosoma:	1	----	----
Helicopsyche:	1	----	----
Hydropsyche:	2.5	----	----
Ironoquia:	0	----	----
Neophylax:	2	----	----
Others:*	2	----	----
	2	----	----
	2	----	----
	2	----	----
LEPIDOPTERA			
Cataclysta:	3	----	----
*Others:	3	----	----
	3	----	----
BEETLES			
Ectopria:	1	----	----
Helichus:	2	----	----
Optioservus:	3	----	----
Psephenus:	2	----	----
Stenelmis:	2.5	----	----
*Others:	2.5	----	----
	2.5	----	----
	2.5	----	----
DIPTERA			
Atherix:	2	----	----
Chironomidae:	----	----	----
Chrysops:	2	----	----
Eriocera:	1	----	----
+ Eristalis(Lit.):	5	----	----
Hemerodromia:	2	----	----
Hexatoma:	2	----	----
Psychodidae:	4	----	----
Simuliidae:	3	----	----
Tabanus:	1.5	----	----
Tipula:	2	----	----
**Others:	2	----	----
	2	----	----
	2	----	----
HYDRACARINA	2	----	----
TOTAL		----	----

TAXA>=25%	#	%
--------------	----	----
--------------	----	----
--------------	----	----

* - Discriminate to Genus

** - Discriminate to Family

\+ - Literature value not derived from CWC data. Organisms were not found in that study.

TABLE 3

STATIONS AT WHICH THE NUMBER OF ORGANISMS PER SAMPLE WAS LESS THAN 100

Station	Date	Original Sample Data	Adjusted Data
Ebs-1	08/18/64	69	69
S-2	12/15/64	58	44
Sh-1	12/16/64	63	63
Sh-1	05/31/65	112	80
St-9	09/02/64	93	93
Jf-3	05/03/65	98	98
Jf1-2	05/03/65	73	73

TABLE 4

CALCULATING TAXA/100 ORGANISMS

1. Determine which taxa* are greater than or equal to 1% of the total sample population, and count them

   Let This Number = A

2. Determine which taxa are less than 1% of the total sample population and calculate the sum of individuals in these taxa.

   Let This Sum = B

3. Calculate what percentage B is of the total sample population.

   Let This Percentage = C%

4. Taxa/100 Organisms = A + C

*Count all taxa including each "others" entry as a separate taxa. However, count "uncertain *Stenonema*" as a separate taxon only if none of the *Stenonema* were more fully identified.

TABLE 5

HOW WATER QUALITY NUMBERS WERE ASSIGNED TO OLIGOCHAETES AND CHIRONOMIDS GIVEN THE NUMBER OF TAXA/100 ORGANISMS

Taxa/100 Organisms (from table 4)	Water Quality Number For Oligochaetes and Chironomids
0 - 4	5
5 - 9	4
10 - 19*	3 (or 4)*
Greater Than or Equal to 20	2

*If diversity (taxa/100 organisms) is 10, 11, 12, or 13, and the number of oligochaetes + chironomids is greater than or equal to 50% of the total sample population, assign a water quality number of 4.

TABLE 6

GUIDELINES TO SHOW WHEN A TAXON THAT WAS GREATER THAN 25% OF THE TOTAL SAMPLE POPULATION WAS REDUCED TO 25%

1. When taxa/100 organisms was greater than or equal to 14, any taxon over 25% was adjusted to 25%.

2. When taxa/100 organisms was 10 - 13, all taxa were adjusted to 25% except oligochaetes and chironomids. If oligochaetes and chironomids together comprised less than 50% of the sample population, each of them was also reduced to 25%; if they were at least 50% of the population, they were not adjusted.

3. When taxa/100 organisms was less than 10, no taxon over 25% was adjusted to 25%.

TABLE 7

HOW TAXA THAT WERE GREATER THAN 25% OF THE TOTAL SAMPLE POPULATION WERE ADJUSTED DOWN TO 25%

A. Given one taxon greater than 25%*

Step

1. A = the number of organisms in the sample population.

2. B = the number of organisms in the taxon that is greater than 25% of the sample population.

3. C = 1.333B - .333A

Derivation of C:

Let C = the amount to subtract from B (and A) to adjust B to 25%.

Then $\frac{B-C}{A-C} = .25$

$$\begin{aligned} B-C &= .25A - .25C \\ B &= .25A + .75C \\ .75C &= B - .25A \\ C &= 1.333B - .333A \end{aligned}$$

4. A - C = the number of organisms in the adjusted population.

   B - C = 25% of the adjusted population (the adjusted value for B)

* After making this adjustment, check to see whether the reduction in population size has resulted in another taxon rising to above 25% of this adjusted population. If one has, then an adjustment must be made to these new results.

TABLE 7 CONTINUED

B. Given two taxa greater than or equal to 25%*

Step

1. A = the number of organisms in the sample population.

2. B = the number of organisms in the taxon that is most over 25% of the sample population.

   C = the number of organisms in the taxon that is least over 25% of the sample population.

3. D = B - C; D is the amount to subtract from B so that B will equal C in subsequent steps.

4. E = A - D; E is the new population size resulting from the reduction of B to equal C in step 3.

5. F = 2C - .5E

   Derivation of F:

   Let F = the amount to subtract from each of the two taxa over 25% (each now equal to C) so that together they will total 50% of the adjusted population.

   Then $\frac{(C-F)+(C-F)}{(E-2F)} = .5$

$$
\begin{aligned}
2C - 2F &= .5E - F \\
2C - F &= .5E \\
-F &= .5E - 2C \\
F &= 2C - .5E
\end{aligned}
$$

6. E - 2F = the number of organisms in the adjusted population.

   C - F = 25% of the adjusted population (the adjusted value for both B and C).

* After making this adjustment, check to see whether the reduction in population size has resulted in another taxon rising to above 25% of this adjusted population. If one has, then an adjustment must be made to these new results.

TABLE 7 CONTINUED

C. Given three taxa greater than or equal to 25%.

Step

1. A = the number of organisms in the sample population.

2. B = the number of organisms in the taxon that is most over 25% of the sample population.

   C = the number of organisms in the taxon that is medially over 25% of the sample population.

   D = the number of organisms in the taxon that is least over 25% of the sample population.

3. E = B - D; E is the amount to subtract from B so that B will equal D in subsequent stages.

   F = C - D; F is the amount to subtract from C so that C will equal D in subsequent stages.

4. G = A - E - F; G is the new population size resulting from the reductions of B and C to equal D in step 3.

5. H = 4D - G

   Derivation of H:

   Let H = the amount to subtract from each of the three taxa over 25% (each now equal to D) so that together they will total 75% of the adjusted population.

   Then $$\frac{(D-H)+(D-H)+(D-H)}{G-3H} = .75$$

   $$\begin{aligned} 3D - 3H &= .75G - 2.25H \\ 3D &= .75G + .75H \\ .75H &= 3D - .75G \\ H &= 4D - G \end{aligned}$$

6. G - 3H = the number of organisms in the adjusted population.

   D - H = 25% of the adjusted population (the adjusted value for B, C, and D).

TABLE 8

RANK CORRELATIONS BETWEEN THE BIOTIC INDEX AND WATER QUALITY (ESTIMATED FROM CHEMICAL AND BACTERIOLOGICAL DATA). THE .001 LEVEL OF SIGNIFICANCE IS .481

	Using Adjusted Biotic Index	Using Unadjusted Biotic Index
Annual Average	.815	.795
Summer	.697	.652
Fall	.611	.587
Winter	.747	.706
Spring	.831	.823

TABLE 9

THE RELATIONSHIP BETWEEN BIOTIC INDEX (UNADJUSTED OR ADJUSTED) AND WATER QUALITY

Amount of Pollution Or Stress	Using Data Taken As A Whole, Disregarding Seasons	Using Annual Average Biotic Index Values	Using Summer Values	Using Fall Values	Using Winter Values	Using Spring Values
Little or None	0.0 - 2.2*	0.0 - 2.4	0.0 - 2.5	0.0 - 2.2	0.0 - 2.2	0.0 - 2.2*
Minor	2.3* - 2.6	2.5 - 2.6	2.6	2.3 - 2.6	2.3 - 2.6	2.3* - 2.6
Moderate	2.7 - 3.5	2.7 - 3.5	2.7 - 3.5	2.7 - 3.5	2.7 - 3.5	2.7 - 3.5
Considerable	3.6 - 4.0	3.6 - 4.0	3.6 - 4.0	3.6 - 4.0	3.6 - 4.0	3.6 - 4.0
Severe	4.1 - 5.0	4.1 - 5.0	4.1 - 5.0	4.1 - 5.0	4.1 - 5.0	4.1 - 5.0

*For unadjusted Biotic Indices one might desire to reduce these numbers by 0.1, see table 10.

TABLE 10. A comparison between unadjusted biotic index values and relative degrees of pollution. The circles represent stations with known sources of pollution and correspond to the circles in table 12. Their degree of darkness suggests the amount of pollution. The plusses represent stations for which no obvious pollution sources were recorded.

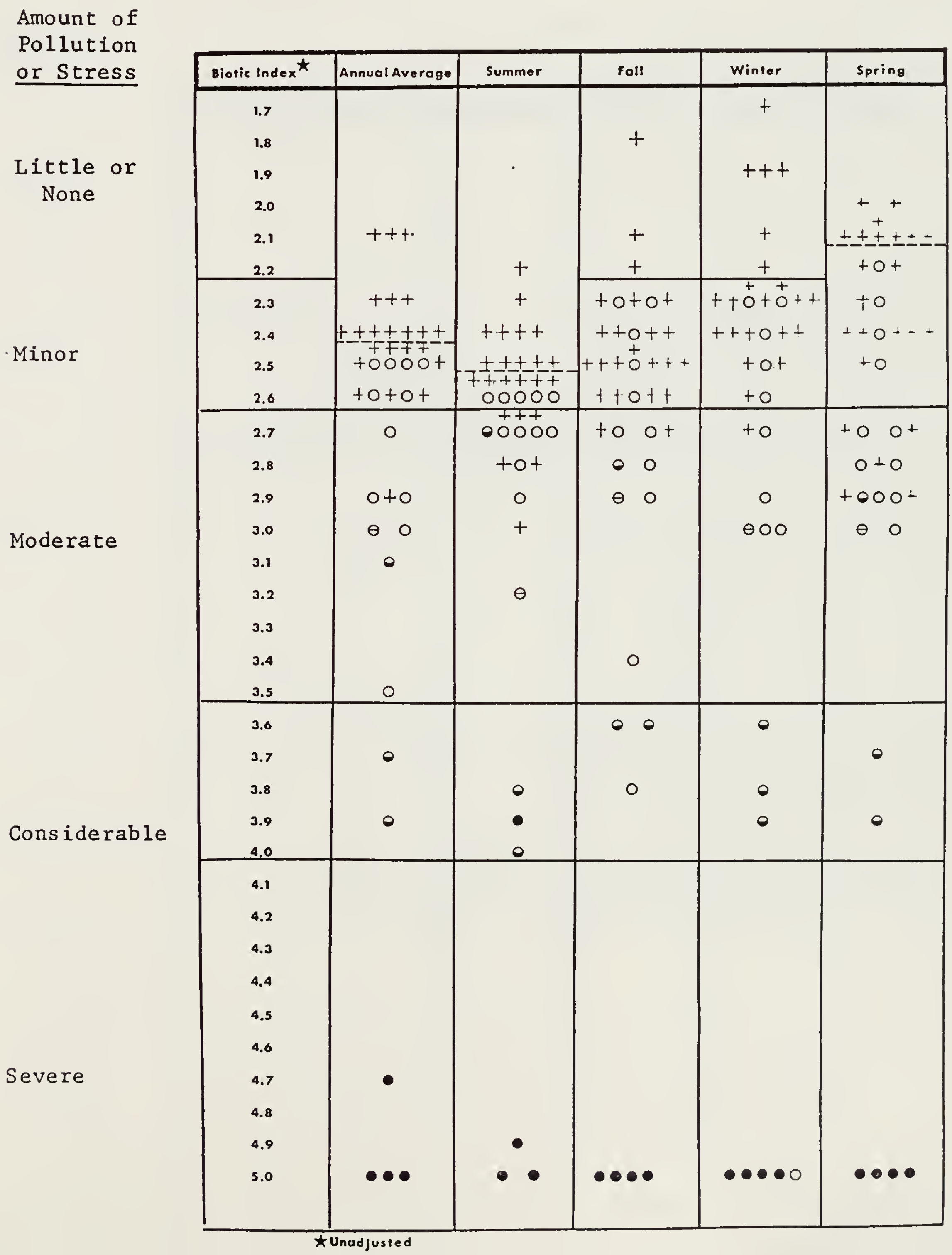


TABLE 11. A comparison between adjusted biotic index values and relative degrees of pollution. The circles represent stations with known sources of pollution and correspond to the circles in table 12. Their degree of darkness suggests the amount of pollution. The plusses represent stations for which no obvious pollution sources were recorded.

Amount of Pollution or Stress	Biotic Index*	Annual Average	Summer	Fall	Winter	Spring
Little or None	1.7				+	
	1.8			+		
	1.9				+++	
	2.0					++
	2.1	+++		+	+	+++++++
	2.2			+		++
Minor	2.3	++++	++	+○++	+++ +○+++	○+○
	2.4	+++++++ +++++++	+++++	++++++ ○ ○	+○+○+++	++○+++
	2.5	○○○○	++++++ ++++++	++++ ++○++	+○++	+○+
	2.6	○+○	+○○○○○+	++○++	○+○+	○
Moderate	2.7	○	+◒○○○○	◒○○+	○	○+
	2.8		○	○	○	◒○○+
	2.9	○+○	○	⊖ ○	○+	○+○
	3.0	◒⊖○	+		⊖ ○	⊖+○
	3.1					
	3.2		⊖			
	3.3					
	3.4			○		
	3.5	○				
Considerable	3.6			◒ ◒	◒	
	3.7	◒				◒
	3.8		◒	○	◒	
	3.9	◒	●		◒	◒
	4.0		◒			
Severe	4.1					
	4.2					
	4.3					
	4.4					
	4.5					
	4.6					
	4.7	●				
	4.8					
	4.9		●			
	5.0	●●●	● ●	●●●●	●●●●○	●●●●

*Adjusted

TABLE 12

POLLUTION SOURCES RECORDED BY THE MISSOURI CLEAN WATER COMMISSION [8]
FOR THE STATIONS USED TO DEVELOP THIS BIOTIC INDEX

Amount of* Pollution Or Stress Table 9	Station	Symbols *** Used To Construct Tables 10 & 11	Adjusted Biotic Index Seasons Averaged	Station Characteristics**
	E-1	+	2.08	Pineville
	E-3	+	2.09	R
	E ls-1	+	2.10	
	E bs-1	+	2.25	
	E b-1	+	2.30	G
	J-2	+	2.30	C
Little	E-2	+	2.32	R
	J f-1	+	2.37	C
	J-7	+	2.37	
or	J-4	+	2.38	U, I
	E i-1	+	2.39	G
	J fl-2	+	2.39	
None	J-1	+	2.40	
	J c-1	+	2.42	
	S c-3	+	2.45	
	E i-2	O	2.45	Below poultry and cheese processing at Anderson, R, G
	J-8	+	2.47	2 miles below small community, R, below J-6
	S s-10	O	2.49	3 miles below municipal waste treatment facility, U
	S-5	+	2.50	I
	J-3	+	2.50	U,I, below lake, much bedrock
Minor	J f-2	+	2.50	U, below lake
	S s-4	+	2.52	
	J fl-1	O	2.54	1 mile below Cassville lagoon
	S-3	O	2.54	2 1/2 miles below polluted S-2
	S s-3	+	2.54	
	J-6	O	2.55	James River 14 miles below polluted Wilson Creek (Jw-),R
	Sc-2	O	2.57	4 miles below a small municipal lagoon, C
	S c-1	+	2.59	C
	J f-4	O	2.68	6 miles below polluted Jf-3
Moderate	J-5	O	2.86	James River 6 miles below polluted Wilson Creek (Jw-), cabins, fish kill next year

TABLE 12 CONTINUED

	J p-1	+	2.87	U-
	S-4	○	2.90	Roughly 20 miles below polluted Sw-1
Moderate	S-1	○	2.98	1/2 mile below trout farm and hatchery
	S-2	◒	3.01	1/2 mile below chemical industry in Verona
	J s-1	⊖	3.03	U+, former fish kills 1/4 mile below lime and concrete plants
	S h-1	○	3.49	14 miles below small municipal STP at Marionville, small stream size
	J f-3	◒	3.67	1/2 mile below cheese plant and municipal waste from Ozark
Considerable	S w-1	◒	3.85	1 mile below milk industry waste and sewage from Mt. Vernon
	S t-9	●	4.72	3 miles below Joplin STP
Severe	J w-2	●	4.97	6 miles below Springfield STP
	J wsp-1	●	4.99	2 miles below Springfield STP
	J w-1	●	5.00	2 miles below Springfield STP

*Based on Annual Average Biotic Index Values (Adjusted).

**Legend
R = resort or recreational area
U = built up area
+ = a lot
- = a little
C = row crops in area
I = irrigation
G = gravel removal
STP = sewage treatment plant

***The circles represent stations with known sources of pollution. Their degree of darkness suggests the amount of pollution. The plusses represent stations for which no obvious pollution sources were recorded.

Table 13. Biotic index values calculated from Missouri Clean Water Commission data.[9] The stations are ranked according to their annual average biotic index values, and their chemical-bacteriological rank is given. Station locations are shown in figure 1.

A. UNADJUSTED BIOTIC INDEX VALUES

Station	Annual Average	Summer	Fall	Winter	Spring	Chemical-Bact. Rank	Annual Average Biotic Index Rank
E-1	2.08	2.40	1.84	1.89	2.20	3	1
E 1s-1	2.09	2.22	2.34	1.69	2.10	8	2
E-3	2.10	2.30	2.10	1.92	2.06	5	3
Ebs-1	2.26	2.50	2.52	1.94	2.07	1	4
J-2	2.30	2.43	2.35	2.28	2.12	12	5.5
E b-1	2.30	2.40	2.29	2.06	2.44	9	5.5
J-7	2.36	2.57	2.20	2.31	2.34	22.5	7.5
E-2	2.36	2.61	2.38	2.40	2.04	2	7.5
E i-1	2.38	2.57	2.60	2.26	2.08	4	9
J-4	2.39	2.35	2.38	2.38	2.43	19	10
J f1-2	2.40	2.53	2.47	2.58	2.02	7	11
J f-1	2.42	2.66	2.59	2.39	2.05	13	12
J c-1	2.44	2.75	2.38	2.24	2.37	11	13
S c-3	2.46	2.55	2.47	2.34	2.46	24	15.5
S-5	2.46	2.52	2.58	2.30	2.44	22.5	15.5
E i-2	2.46	2.64	2.51	2.35	2.35	10	15.5
J-1	2.46	2.79	2.53	2.40	2.13	20.5	15.5
J-8	2.47	2.49	2.54	2.46	2.38	25	18
S s-10	2.48	2.61	2.31	2.34	2.66	29	19
J f1-1	2.51	2.62	2.55	2.62	2.24	17	20
S s-4	2.52	2.72	2.34	2.26	2.77	20.5	21
S-3	2.54	2.57	2.33	2.72	2.53	31.5	22.5
S s-3	2.54	2.61	2.52	2.34	2.70	14	22.5
J-6	2.55	2.73	2.65	2.49	2.31	36	24
J-3	2.56	2.55	2.46	2.49	2.72	18	25
S c-2	2.57	2.74	2.43	2.34	2.76	33	26
J f-2	2.58	2.74	2.69	2.65	2.24	6	27
S c-1	2.62	2.52	2.61	2.43	2.92	34	28
J f-4	2.71	2.69	2.72	2.66	2.78	15	29
J p-1	2.88	2.97	2.74	2.91	2.91	35	30
J-5	2.89	2.81	2.80	3.00	2.93	39	31
S-4	2.90	2.88	2.87	2.95	2.91	30	32
S-1	3.01	2.64	3.83	2.90	2.68	16	33
J s-1	3.03	3.19	2.92	3.03	2.97	31.5	34
S-2	3.05	2.74	2.80	3.75	2.91	27.5	35
S h-1	3.49	2.65	3.41	4.95	2.96	26	36
J f-3	3.67	3.79	3.57	3.63	3.68	27.5	37
S w-1	3.85	3.97	3.62	3.91	3.90	37	38
S t-9	4.72	3.91	4.98	5.00	4.99	38	39
J w-2	4.97	4.94	4.97	4.98	5.00	41.5	40
J wsp-1	4.99	4.99	4.99	4.99	4.98	41.5	41
J w-1	5.00	4.99	5.00	5.00	5.00	40	42

Table 13, cont. Biotic index values calculated from Missouri Clean Water Commission data.[9] The stations are ranked according to their annual average biotic index values, and their chemical-bacteriological rank is given. Station locations are shown in figure 1.

B. ADJUSTED BIOTIC INDEX VALUES

Station	Annual Average	Summer	Fall	Winter	Spring	Chemical-Bact. Rank	Annual Average Biotic Index Rank
E-1	2.08	2.38	1.84	1.88	2.20	3	1
E-3	2.09	2.26	2.10	1.92	2.06	5	2
E ls-1	2.10	2.25	2.34	1.69	2.10	8	3
E bs-1	2.25	2.50	2.52	1.94	2.05	1	4
E b-1	2.30	2.40	2.29	2.07	2.44	9	5.5
J-2	2.30	2.44	2.37	2.28	2.12	12	5.5
E-2	2.32	2.57	2.35	2.30	2.04	2	7
J f-1	2.37	2.56	2.49	2.36	2.05	13	8.5
J-7	2.37	2.57	2.20	2.40	2.30	22.5	8.5
J-4	2.38	2.35	2.37	2.38	2.41	19	10
E i-1	2.39	2.57	2.59	2.31	2.08	4	11.5
J fl-2	2.39	2.53	2.46	2.56	2.02	7	11.5
J-1	2.40	2.57	2.53	2.36	2.13	20.5	13
J c-1	2.42	2.62	2.42	2.27	2.35	11	14
S c-3	2.45	2.53	2.47	2.34	2.46	24	15.5
E i-2	2.45	2.63	2.51	2.35	2.32	10	15.5
J-8	2.47	2.49	2.54	2.46	2.38	25	17
S s-10	2.49	2.61	2.31	2.41	2.62	29	18
J-3	2.50	2.55	2.46	2.49	2.50	18	20
S-5	2.50	2.52	2.58	2.46	2.44	22.5	20
J f-2	2.50	2.54	2.62	2.61	2.24	6	20
S s-4	2.52	2.69	2.36	2.27	2.77	20.5	22
J fl-1	2.54	2.62	2.55	2.63	2.35	17	24
S-3	2.54	2.57	2.35	2.71	2.53	31.5	24
S s-3	2.54	2.61	2.52	2.34	2.70	14	24
J-6	2.55	2.73	2.65	2.49	2.31	36	26
S c-2	2.57	2.74	2.43	2.34	2.76	33	27
S c-1	2.59	2.38	2.61	2.43	2.95	34	28
J f-4	2.68	2.69	2.66	2.60	2.75	15	29
J-5	2.86	2.81	2.79	3.00	2.85	39	30
J p-1	2.87	2.97	2.74	2.86	2.91	35	31
S-4	2.90	2.88	2.86	2.94	2.91	30	32
S-1	2.98	2.64	3.83	2.76	2.68	16	33
S-2	3.01	2.74	2.74	3.75	2.82	27.5	34
J s-1	3.03	3.19	2.91	3.03	2.97	31.5	35
S h-1	3.49	2.65	3.41	4.95	2.95	26	36
J f-3	3.67	3.79	3.57	3.63	3.68	27.5	37
S w-1	3.85	3.97	3.62	3.91	3.90	37	38
S t-9	4.72	3.91	4.98	5.00	4.99	38	39
J w-2	4.97	4.94	4.97	4.98	5.00	41.5	40
J wsp-1	4.99	4.99	4.99	4.99	4.98	41.5	41
J w-1	5.00	4.99	5.00	5.00	5.00	40	42

Table 14. The Missouri Clean Water Commission chemical-bacteriological data[8] used in this report.*

STATION	SEASON	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
E-1	SU	102	260	0.001	0.5	0.35	0.05	0	51	50	7	4
E-1	F	99	250	0	0.2	0.4	0	0	8	20	1	5
E-1	W	111	250	0.001	0.6	0.25	0.11	0	20	0	1	4.7
E-1	SP	123	220	0.005	1.4	0.45	0	0	116	42	1	3.9
E-3	SU	107	230	0		0.55		0	10	42	10	
E-3	F	109	240	0.005		0.55		0	100	40	1	
E-3	W	97	240	0.001	0.9	0.35		0	120	0	1	
E-3	SP	146	200	0.005	1.5	0.35	0.01	0	160	38	1	
Els-1	SU	92	240	0	0.5	0.25	0.12	0	200		6	8
Els-1	F	115	280	0.001	0.3	0.3	0.01	0	10	40	1	7.4
Els-1	W	113	250	0.001	0.3	0.45	0.18	0	0	0	1	7
Els-1	SP	124		0.008	1.6	0.45	0.06	0	78	84	10	2.8
Ebs-1	SU	126	230	0	0.4	0.35	0.07	0	35		1	4
Ebs-1	F	122	260	0.005	0.1	0.9	0.04	0	0	46	1	3.8
Ebs-1	W	116	250	0.001	1.1	0.25	0.13	0	26	6	1	3.2
Ebs-1	SP	124	190	0.005	1.3	0.45	0	0	150	60	6	4.2
E b-1	SU	84	250	0	0.7	0.25	0.02	0	42	91	7	6
E b-1	F	72	260	0	0.2	0.7	0	0	94	4		7
E b-1	W	118	220	0.001	1	0.45	0.22	0	12	6	1	7.1
E b-1	SP	119	200	0.005	1.2	0.35	0.03	0	110	46	1	5.4
J-2	SU	72	290	0	0.1	0.45	0.01		100		1	
J-2	F	62	280	0	0.01	0.7	0.01		110	370	6	
J-2	W	101	280	0		0.2			6	4	1	
J-2	SP	117	200	0.005	0.8	0.35	0.01		54	10	10	
E-2	SU	96	240	0	0.1	0.25	0.09	0	52	53	5	4
E-2	F	114	230	0	0.6	0.45	0.02	0	4	22	1	3.7
E-2	W	112	250	0.007	0.2	0.3	0.08	0	6	0	1	4.1
E-2	SP	131	200	0.005	1.2	0.45	0	0	48	92	1	3.4
Jf-1	SU	80	270	0.001	0.3	0.35	0.05	0.1	280	85	5	4
Jf-1	F	76	280	0.001	0.1	0.55	0	0	4	4	1	3.7
Jf-1	W	99	270	0.005	0.4	0.45	0.08	0	0	0	1	9
Jf-1	SP	131	225	0.005	1	0.7	0.01	0.1	34	18	1	4.1

Table 14, cont. The Missouri Clean Water Commission chemical-bacteriological data[8] used in this report.*

STATION	SEASON	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
J-7	SU	151	325	0.007	1	0.55	1.5	0.1			8	17
J-7	F	114	380	0.008	2.1	0.2	1.9	0.2	24	4	9	20
J-7	W	94	340	0.015	2.2	0.55	0.37	0.1	24	2		9.8
J-7	SP	152	250	0.015	2.3	0.45	0.12	0.1	26	10	9	5.8
J-4	SU	111	320	0.005	1.3	0.7	0.07	0	400	27	15	37
J-4	F	91	350	0.005	0.9	0.6	0.09	0	70	38	6	7
J-4	W	93	320	0.005	0.9	0.35	0.07	0	0	2	1	6.8
J-4	SP	116	250	0.015	2.1	0.35	0.09	0	180	38	6	5.4
Ei-1	SU	117	220	0	1.1	0.25	0.09	0	26	38	8	3
Ei-1	F	114	230	0.005	0.4	0.7	0	0	12	40	1	4.1
Ei-1	W	106	220	0.001	1.8	0.35	0.17	0	2	4	1	3.2
Ei-1	SP	143	190	0.005	2	0.45	0.01	0	42	24	1	2.8
Jfl-2	SU	78	270	0.001		0.25			0		1	
Jfl-2	F	85	270	0.005	0.3	0.7	0	0	22	74	1	3.5
Jfl-2	W	116	250	0.005	1.2	1.1	0.16	0	2	0	1	4
Jfl-2	SP	117	210	0.005	1.2	0.5	0	0	160	62	1	3.8
J-1	SU	88	290	0	0.2	0.9	0.08	0	200		1	7
J-1	F	82	300	0	0.1	0.55	0.08	0	22	120	5	6
J-1	W	97	270	0.007	0.5	0.3	0.1	0	24	2	1	7
J-1	SP	115	200	0.03	1.1	5.5	0.06	0	62	8	15	4.7
Jc-1	SU	123	255	0.015	1.7	0.35	0.06	0	50	48	6	6.5
Jc-1	F	111	290	0.005	1.6	0.35	0.12	0	70	130	1	4
Jc-1	W	105	290	0.005	1.8	0.25	0.12	0.1	28	4	1	2.8
Jc-1	SP	125	250	0.05	2.7	0.25	0.09	0	280	12	6	3.7
Sc-3	SU	93	240	0.005	0.8	0.35	0.06	0	450	440	22	3
Sc-3	F	101	220	0.005	2.5	0.7	0.04	0	18	80	1	4.9
Sc-3	W	118	250	0.015	1.6	0.45	0.38	0	6	4	10	4.9
Sc-3	SP	94	225	0.005	1.9	0.3	0.14	0	180	84	8	4.3
Ei-2	SU	110	230	0.005	0.7	0.45	0.14	0	800	120	17	5
Ei-2	F	109	230	0.007	0.2	0.3	0.14	0	100	20	1	4.1
Ei-2	W	119	200	0.001	0.8	0.3	0.08	0	34	0	1	3.7
Ei-2	SP	145	210	0.01	1.8	0.7	0.08	0	290	30	1	3.6

Table 14, cont. The Missouri Clean Water Commission chemical-bacteriological data[8] used in this report.*

STATION	SEASON	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
J-8	SU	135	320	0.005	0.3	0.1	1.2	0.1		8	13	15
J-8	F	93	380	0.005	1.3	0.3	2.6	0.2	140	8	10	19
J-8	W	91	340	0.015	2	0.35	0.86	0.1	30	2	1	9.2
J-8	SP	148	250	0.015	2.3	0.45	0.02	0.1	28	0	10	6.7
Ss-10	SU	95	240	0.005	0.1	0.35	0.48	0.1	60	80	15	5
Ss-10	F	94	270	0.005	3.2	0.45	0.04	0	600	400	1	4.7
Ss-10	W	117	240	0.015	6.9	0.55	0.52	0.1	12	0	1	5.1
Ss-10	SP	105	225	0.005	4.7	0.4	0.16	0	300	100	8	3.8
S-5	SU	93	300	0.005	1.4	0.35	0.16	0	24	120	19	6
S-5	F	93	300	0.005	1.6	0.4	0.1	0	14	10	1	6.8
S-5	W	106	250	0.015	2.7	0.45	0.14	0			1	5.5
S-5	SP	92	250	0.005	2.2	0.8	0.03	0		340	29	5.8
J-3	SU	77	300	0.005	0.7	0.45	0.1	0	360		15	8.5
J-3	F	80	310	0.001	0.2	0.7	0.09	0	80	90	6	9
J-3	W	95	320	0.007	0.7	0.35	0.04	0	6	22	1	6.9
J-3	SP	111	250	0.01	1.9	0.35	0.1	0	230	10	12	5.5
Jf-2	SU	110	260	0.001	0.3	0.55			30	33	7	
Jf-2	F	92	280	0.001	0.01	0.6	0.01		4	0	1	
Jf-2	W	103	270	0.005		0.45			0	0	1	
Jf-2	SP	122	225	0.005	0.8	0.55	0.3		40	12	1	
Ss-4	SU	90	250	0.005		0.35			90	160	13	
Ss-4	F	96	250			0.25			0	0	1	
Ss-4	W	124	250			0.7			2	6	1	
Ss-4	SP	100	225	0.005	2	1.2	1.8		190	7000	10	
Jfl-1	SU	111	260	0.008	1.4	0.2	0.05	0	270	4	6	6
Jfl-1	F	131	260	0.01	0.8	0.55	0.14	0.2	18	290	1	5.4
Jfl-1	W	84	250	0.001	0.4	0.35	0.13	0.2	1500	92	1	4.8
Jfl-1	SP	128	225	0.008	2.2	0.35	0	0	1900	170	5	4.3
S-3	SU	114	260	0.01	1.2	0.7	0.26	0.1	340	200	9	8
S-3	F	102	300	0.03	1.9	0.8	0.04	0	12	140	1	12
S-3	W	158	225	0.015	1.9	0.01	0.21	0	1000	20	1	8
S-3	SP	108	250	0.015	2.2	0.6	0.06	0	840	40	8	8.6

Table 14, cont. The Missouri Clean Water Commission chemical-bacteriological data[8] used in this report.*

STATION	SEASON	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
Ss-3	SU	111	240	0.005		0.55			30	600	7	
Ss-3	F	90	240			0.35			0	0	1	
Ss-3	W	113	220			0.35	0.01		2	0	1	
Ss-3	SP	111	225	0.005	2	0.9	0.2		180	140	1	
J-6	SU	124	380	0.01	0.01	0.45	3			14	14	
J-6	F	61	450	0.11	2	0.9	6		20	10	5	
J-6	W	97	350	0.035		0.9			92	0	1	
J-6	SP	116	300	0.06	0.6	0.5	0.4		580	16	9	
Sc-2	SU	89	250	0.005	2	0.45	0.01		450	320	17	
Sc-2	F	101	250	0.005	2	0.45			0	60	1	
Sc-2	W	128	260	0.015	4	0.7	0.3		16	2	1	
Sc-2	SP	115	240	0.005		0.6	0.01		46	68	6	
Sc-1	SU	89	250	0.005	1.2	0.25	0.04	0	800	300	18	4
Sc-1	F	103	250	0.005	2.9	0.45	0.8	0	38	100	5	5.1
Sc-1	W	110	260	0.015	2.5	0.55	0.29	0.1	6	24	1	5.3
Sc-1	SP	108	225	0.005	2.7	1	0	0	120	100	1	5.4
Jf-4	SU	107	300	0.005	0.9	0.35	0.13	0	280	120	17	4
Jf-4	F	92	320	0.005	0.4	0.55	0	0	6	8	8	4.1
Jf-4	W	106	300	0.005	1	0.7	0.14	0	4	6	1	4.8
Jf-4	SP	148	250	0.005	2.1	0.7	0	0	140	12	1	4.6
J-5	SU	113	460	0.08	0.1	0.3	0.16	0.3	1000	100	14	36
J-5	F	45	550	0.125	2.5	3.5	11	0.8	460	58	9	48
J-5	W	70	430	0.08	2.3	3.2	1.9	0.2	5200	10	5	19
J-5	SP	132	300	0.085	2.7	0.9	0.21	0.1	2300	40	11	9.8
Jp-1	SU	93	300	0.015	4.3	0.35	0.09	0.1	5200		1	13
Jp-1	F	88	400	0.005	3.6	0.9	0.13	0.1	210	410	1	11
Jp-1	W	116	370	0.005	3.2	0.35	0.1	0	12	2	1	8.3
Jp-1	SP	132	300	0.005	4.1	0.45	0.06	0	290	10	10	7.3
S-4	SU	91	300	0.005	1.9	0.35	0.2	0	63	264	19	8
S-4	F	134	300	0.01	2.3	0.45	0.39	0	34	12	1	8.2
S-4	W	121	250	0.01	2.3	0.4	0.68	0.1	120	8	1	5.7
S-4	SP	88	250	0.015	2.5	0.6	0.09	0	140	70	29	6.4

Table 14, cont. The Missouri Clean Water Commission chemical-bacteriological data[8] used in this report.*

STATION	SEASON	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
S-1	SU	128	280	0.015	2.2	0.35	0.28	0	41	56	7	8
S-1	F	104	300	0.015	2.5	0.3	0.09	0	110	6	1	8.3
S-1	W	119	225	0.005	2.2	0.45	0.09	0	300	2	1	6
S-1	SP	126	250	0.005	2.7	0.6	0	0	480	34	1	6.9
S-2	SU	130	280	0.025	2	0.9			310	110	7	
S-2	F	101	300	0.01		0.7	0.01		62	40	5	
S-2	W	111	225	0.007	2.5	0.45	0.01		90	4	1	
S-2	SP	123	250	0.008	0.1	1	0.01		530	58	8	
Js-1	SU	132	300	0.015	1.7	0.35	0.08	0.1	1400	540	10	13
Js-1	F	158	350	0.01	0.9	0.6	0.14	0.1	770	680	9	16
Js-1	W	109	380	0.015	1.6	0.6	0.07	0	10	26	1	15
Js-1	SP	124	275	0.015	3.8	0.35	0	0.1	4300	170	9	9.4
Sh-1	SU	96	280	0.005		0.7	0.19		120	84	15	
Sh-1	F	116	300	0.005		0.3			4	44	1	
Sh-1	W	120	250	0.015	6	0.45	0.2		80	18	10	
Sh-1	SP	109	275	0.015	0.4	0.2	0.2		400	42	1	
Jf-3	SU	52	300	0.015	0.01	0.25	0.22	0	10000	5000	5	4
Jf-3	F	68	300	0.001	0	0.6	0.16	0.1	1300	300	1	4.1
Jf-3	W	107	300	0.005	0.01	0.3	0.06	0	170	140	1	5.1
Jf-3	SP	130	250	0.008	1.4	0.45	0.11	0.1	5200	50	1	4.7
Sw-1	SU	56	390	0.16		1.2			600	40	5	
Sw-1	F	107	330	0.15		0.7			10000	1100	1	
Sw-1	W	132	250	0.035	0.2	0.35			46000	360	1	
Sw-1	SP	116	300	0.07	2	2.2	3		10000	4300	8	
St-9	SU	80	670	0.15		0.25				130	8	
St-9	F	66	750			2.5			11000	4000	1	
St-9	W	56	700			5	20		67000	570	6	
St-9	SP	107	550	0.15	0.01	1.6	6		88000	350	6	
Jw-2	SU	93	560	0.6	1.9	10	16	1.6	8800		13	63
Jw-2	F	11	800	0.6	0.8	22	22	2.4	2600	1300	15	111
Jw-2	W	64	700	1.1	0.5	32	8.3	0.8	110	170	8	61
Jw-2	SP	104	475	0.15	5.4	10	3.1	0.3	80000	700	15	37

Table 14, cont. The Missouri Clean Water Commission chemical-bacteriological data[8] used in this report.*

STATION	SEASON	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
Jwsp-1	SU	15	650	0.5	0.7	11	17	1.6	40000	2600	22	60
Jwsp-1	F	7	770	0.2	0.3	18	11	2.3	10000	6800	17	28
Jwsp-1	W	42	520	0.07	1.2	16	0.64	0.5	10000	4400	8	35
Jwsp-1	SP	71	450	0.15	4.1	2	21	0.2	9000	1100	15	33
Jw-1	SU	83	800	1.1	0.1	28	27	1.6	340000	560	23	84
Jw-1	F	35	900	1	0.2	26	29	3.9	6000	1200	24	85
Jw-1	W	55	800	0.15	0.2	40	16	1.6	76000	20000	15	67
Jw-1	SP	105	700	0.2	1.7	14	9.1	0.6	230000	3100	13	86

*The above entries vary from original Missouri Clean Water Commission (CWC) data in the following ways:

Parameter	If CWC data was recorded as	We entered
NO2	-0.005	0.001
NO3	-0.1	0.01
	0.005+	0.005
NH4	-0.1	0.01
O-PO4	-0.2+	0.01
	-0.2	0.01
	0.2+	0.2
	0.3+	0.3
	0.4+	0.4
	1.8+	1.8
	3.0+	3
	6.0+	6
Coliform	-2	0
	-50	0
F. Strep	-2	0
	-50	0
Turb.	-5	1

- Denotes less than

Table 15. The relationships between water quality categories and their chemical-bacteriological statistics. All of the Missouri Clean Water Commission chemical data used in this study are included in the statistics. The water quality categories used are based on adjusted annual average biotic index values (table 9).

	DOSat %	COND umhos/cm	NO2 ppm	NO3 ppm	NH4 ppm	O-PO4 ppm	ABS ppm	COLIFORM /100 ml	F.STREP /100 ml	TURB units	CL- ppm
Little or no pollution or stress: Biotic Index = 0.0 - 2.4 (14 stations)											
AVERAGES	108	256	0.005	0.94	0.54	0.13	0.02	68	39	3.67	6.26
MAXIMA	152	380	0.050	2.70	5.50	1.90	0.20	400	370	15.00	37.00
MINIMA	62	190	0	0.01	0.20	0	0	0	0	1.00	2.80
STD. DEVIATIONS	20	41	0.008	0.69	0.69	0.33	0.04	82	57	3.78	5.56
n =	56	55	56	52	56	51	51	55	50	54	47
Minor pollution or stress: Biotic Index = 2.5 - 2.6 (14 stations)											
AVERAGES	106	264	0.011	1.69	0.50	0.46	0.04	238	220	6.43	6.47
MAXIMA	158	450	0.110	6.90	1.20	6.00	0.20	1900	7000	29.00	19.00
MINIMA	61	200	0.001	0.01	0.01	0	0	0	0	1.00	3.00
STD. DEVIATIONS	18	47	0.017	1.28	0.22	1.02	0.06	386	940	6.63	3.20
n =	56	56	52	47	56	47	36	52	54	56	36
Moderate pollution or stress: Biotic Index = 2.7 - 3.5 (8 stations)											
AVERAGES	112	309	0.020	2.23	0.70	0.56	0.08	765	98	6.75	11.70
MAXIMA	158	550	0.125	6.00	3.50	11.00	0.80	5200	680	29.00	48.00
MINIMA	45	225	0.005	0.10	0.20	0	0	4	2	1.00	4.00
STD. DEVIATIONS	22	70	0.029	1.31	0.71	1.97	0.17	1415	160	6.63	10.04
n =	32	32	32	29	32	30	24	32	31	32	24
Considerable pollution or stress: Biotic Index = 3.6 - 4.0 (2 stations)											
AVERAGES	96	303	0.056	0.60	0.76	0.71	0.05	10409	1411	2.88	4.48
MAXIMA	132	390	0.160	2.00	2.20	3.00	0.10	46000	5000	8.00	5.10
MINIMA	52	250	0.001	0	0.25	0.06	0	170	40	1.00	4.00
STD. DEVIATIONS	30	42	0.061	0.80	0.62	1.15	0.05	14046	1904	2.57	0.45
n =	8	8	8	6	8	5	4	8	8	8	4
Severe pollution or stress: Biotic Index = 4.1 - 5.0 (4 stations)											
AVERAGES	62	675	0.437	1.32	14.90	14.72	1.45	65234	3132	13.06	62.50
MAXIMA	107	900	1.100	5.40	40.00	29.00	3.90	340000	20000	24.00	111.00
MINIMA	7	450	0.070	0.01	0.25	0.64	0.20	110	130	1.00	28.00
STD. DEVIATIONS	32	127	0.370	1.59	11.60	8.36	1.03	93523	4875	6.38	24.78
n =	16	16	14	13	16	14	12	15	15	16	12

Figure 1. The Missouri Clean Water Commission sampling stations used in this study.

Legend For Cities, Towns, Rivers and Creeks

1	Exeter	J	James River
2	Purdy	Jc	Crane Creek
3	Cassville	Jf	Finley Creek
4	Crane	Jfl	Flat Creek
5	Billings	Jp	Pearson Creek
6	Galena	Jw	Wilson Creek
7	Clever	Jwsp	Rader Spring
8	Republic		
9	Nixa		
10	Springfield		
11	Ozark		
12	Rogersville		
13	Seymour		
14	Table Rock Lake		

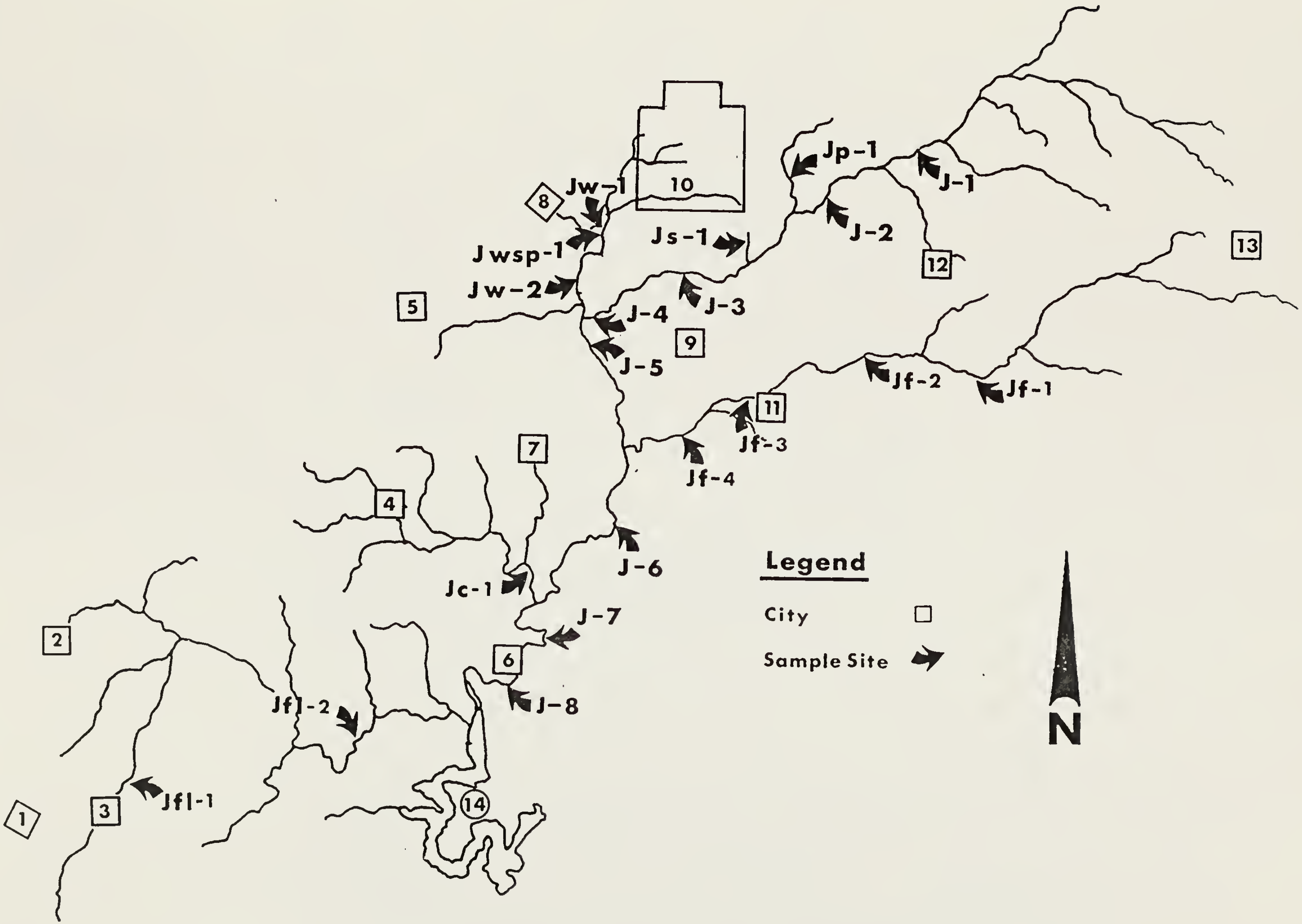

Jp-1
J-1
J-2
12
13
10
8
Jw-1
Jwsp-1
Js-1
Jw-2
J-3
5
J-4
9
J-5
Jf-2
Jf-1
11
Jf-3
Jf-4
7
4
J-6
Legend
City
Sample Site
N
Jc-1
J-7
2
6
J-8
Jfl-2
Jfl-1
3
1
14

Figure 1, cont. The Missouri Clean Water Commission sampling stations used in this study.

<u>Legend For Cities, Towns, Rivers and Creeks</u>

1	Noel	E	Elk River
2	Lanagan	Eb	Buffalo Creek
3	Anderson	Ebs	Big Sugar Creek
4	Pineville	Ei	Indian Creek
5	Seneca	Els	Little Sugar Creek
6	Neosho	S	Spring River
7	Granby	Sc	Center Creek
8	Joplin	Sh	Honey Creek
9	Carl Junction	Ss	Shoal Creek
10	Carthage	St	Turkey Creek
11	Jasper	Sw	Williams Creek
12	Lamar		
13	Golden City		
14	Wheaton		
15	Purdy		
16	Monett		
17	Pierce City		
18	Aurora		
19	Mt. Vernon		

Legend
City
Sample Site
N
12
13
11
9
10
St-9
8
S-5
S-4
Sw-1
19
Sh-1
Sc-3
Sc-2
Sc-1
Ss-10
S-3
18
Ss-4
17
16
S-2
S-1
7
6
Ss-3
5
15
14
Eb-1
Ei-1
E-3
3
Ei-2
2
4
E-1
Ebs-1
1
E-2
Els-1

Figure 2. The adjusted annual average biotic index values corresponding to the stations shown in figure 1.

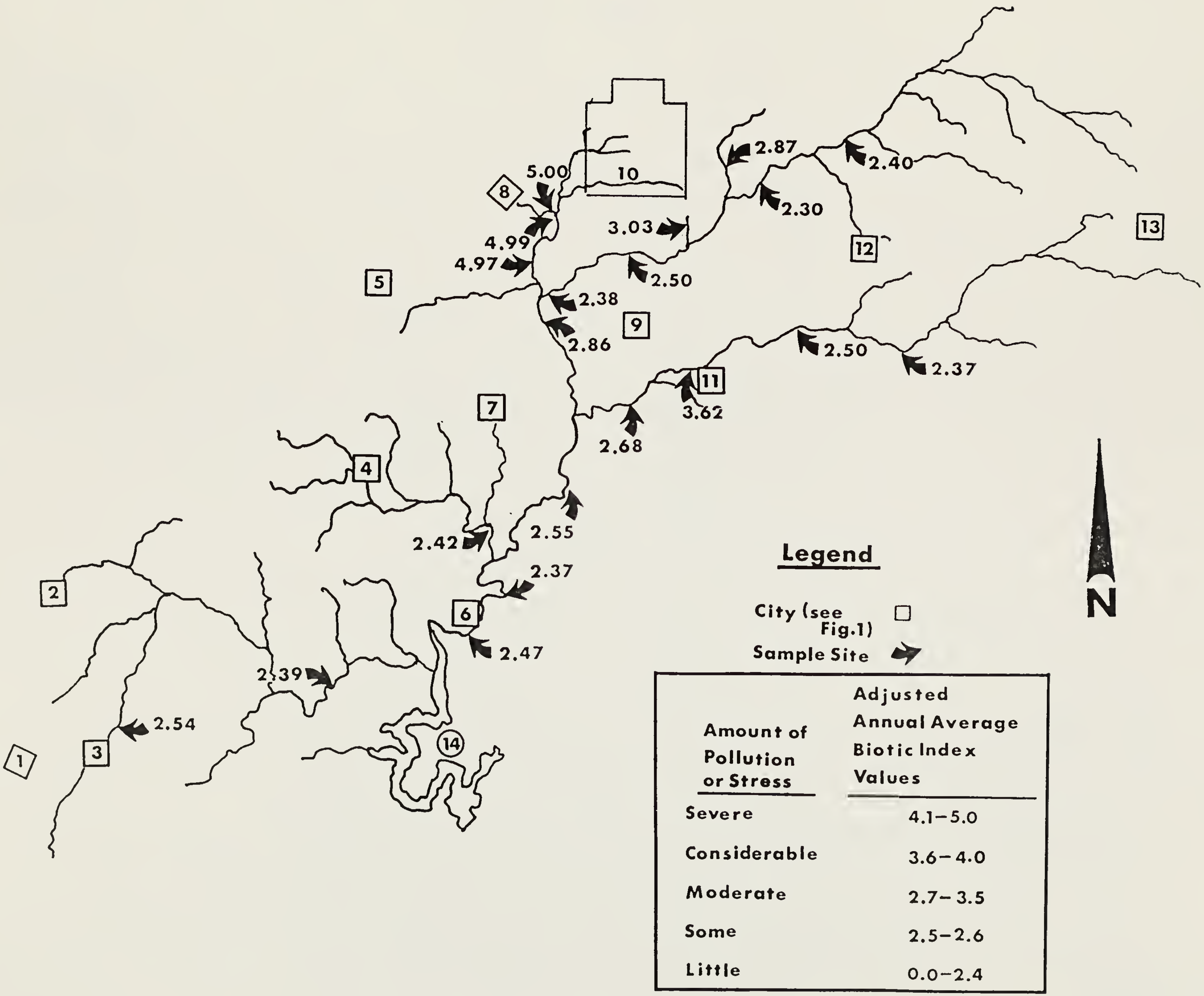
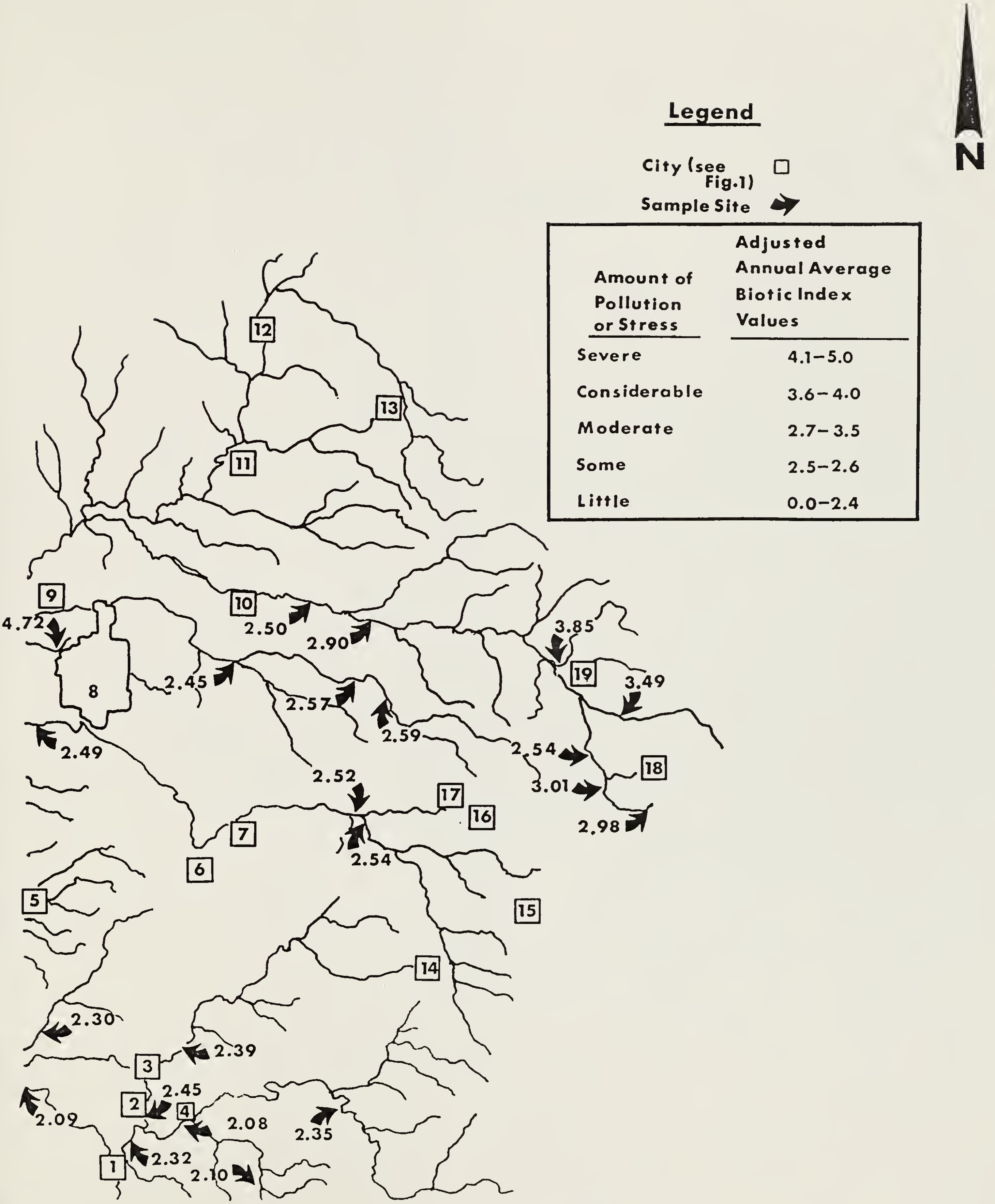
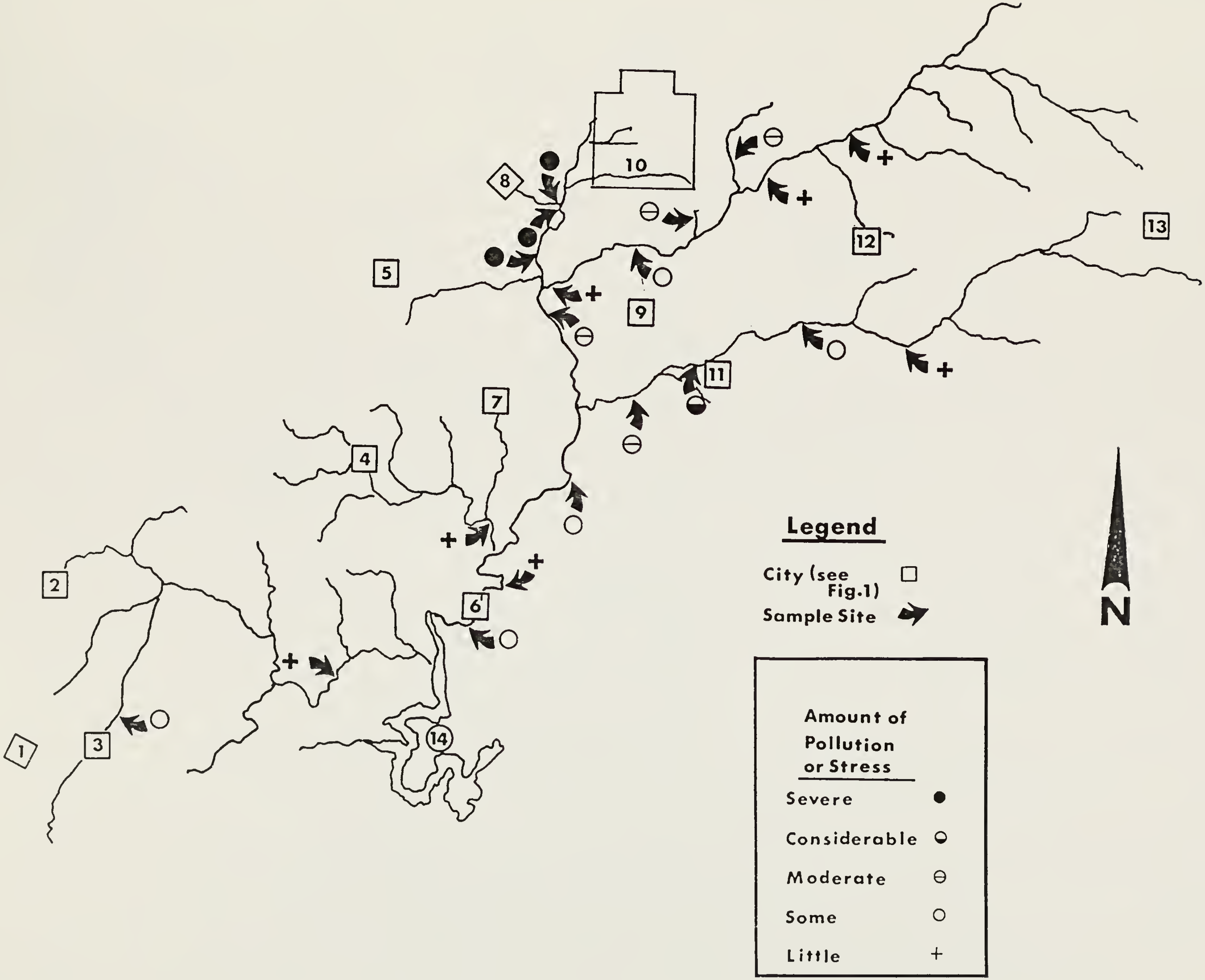

10
8
5.00
4.99
4.97
5
2.38
2.86
9
3.03
2.50
2.87
2.30
2.40
12
13
11
3.62
2.50
2.37
2.68
7
4
2.55
2.42
2.37
2
6
2.47
2.39
2.54
1
3
14
N
Legend
City (see Fig.1)
Sample Site
Amount of Pollution or Stress
Adjusted Annual Average Biotic Index Values
Severe
4.1–5.0
Considerable
3.6–4.0
Moderate
2.7–3.5
Some
2.5–2.6
Little
0.0–2.4

Figure 2, cont. The adjusted annual average biotic index values corresponding to the stations shown in figure 1.



Legend
City (see Fig.1)
Sample Site
Amount of Pollution or Stress
Adjusted Annual Average Biotic Index Values
Severe 4.1–5.0
Considerable 3.6–4.0
Moderate 2.7–3.5
Some 2.5–2.6
Little 0.0–2.4
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
4.72
2.50
2.90
3.85
2.45
2.57
2.59
3.49
2.49
2.54
2.52
3.01
2.98
2.54
2.30
2.39
2.45
2.09
2.08
2.35
2.32
2.10

Figure 3. The water quality categories corresponding to the stations shown in figure 1, based on adjusted annual average biotic index values (figure 2).



1
2
3
4
5
6
7
8
9
10
11
12
13
14
N
Legend
City (see Fig.1)
Sample Site
Amount of Pollution or Stress
Severe
Considerable
Moderate
Some
Little

Figure 3, cont. The water quality categories corresponding to the stations shown in figure 1, based on adjusted annual average biotic index values (figure 2).

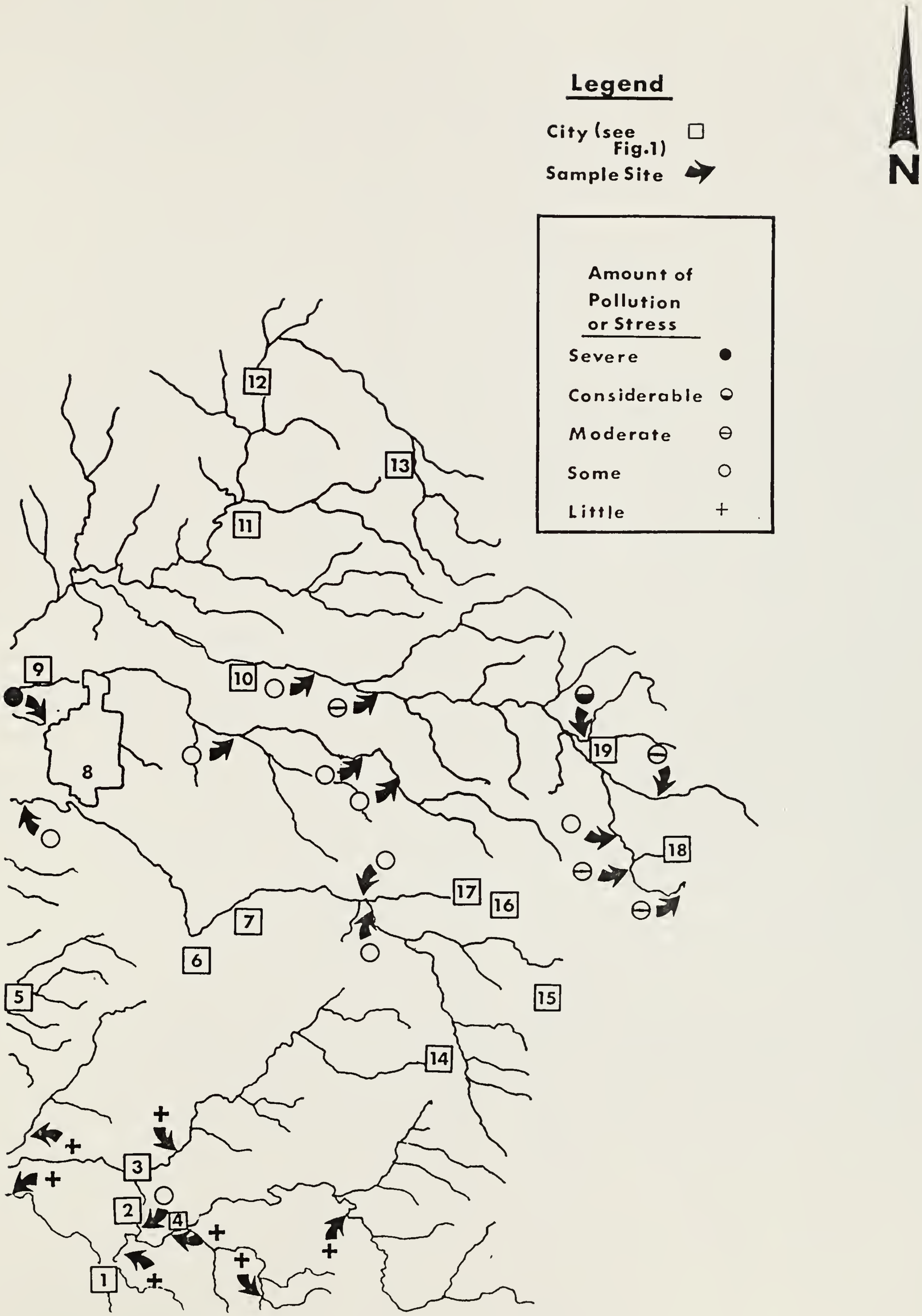

Legend
City (see Fig.1)
Sample Site
Amount of Pollution or Stress
Severe
Considerable
Moderate
Some
Little
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

Figure 4. The relationship between water quality based on the adjusted annual average biotic index and an average of corresponding chemical and bacteriological data.

Adjusted Annual Average Biotic Index	Amount of Pollution or Stress
0 - 2.4	Little or None
2.5 - 2.6	Minor
2.7 - 3.5	Moderate
3.6 - 4.0	Considerable
4.1 - 5.0	Severe

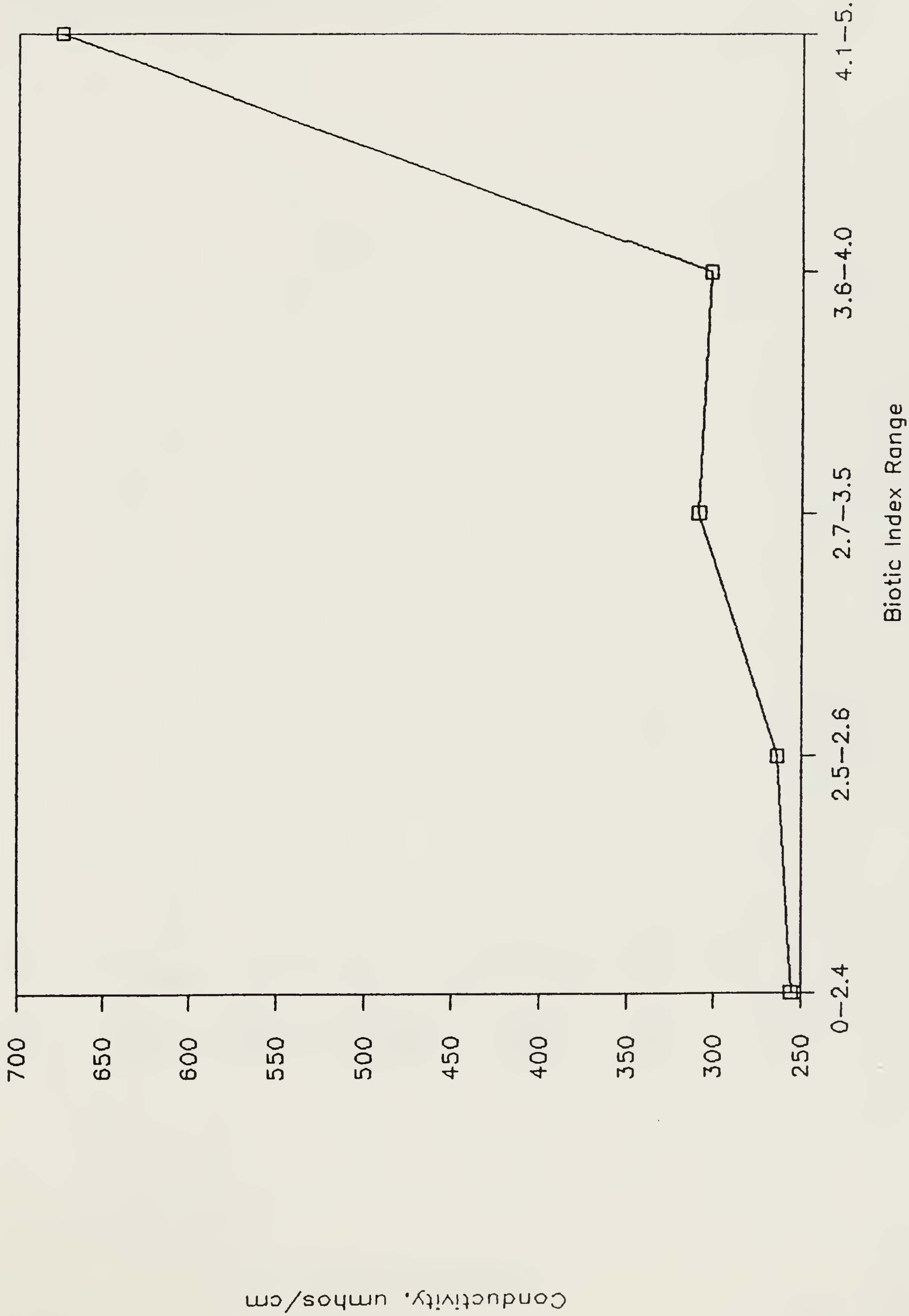

Conductivity, umhos/cm
700
650
600
550
500
450
400
350
300
250
Biotic Index Range
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0

Figure 4b

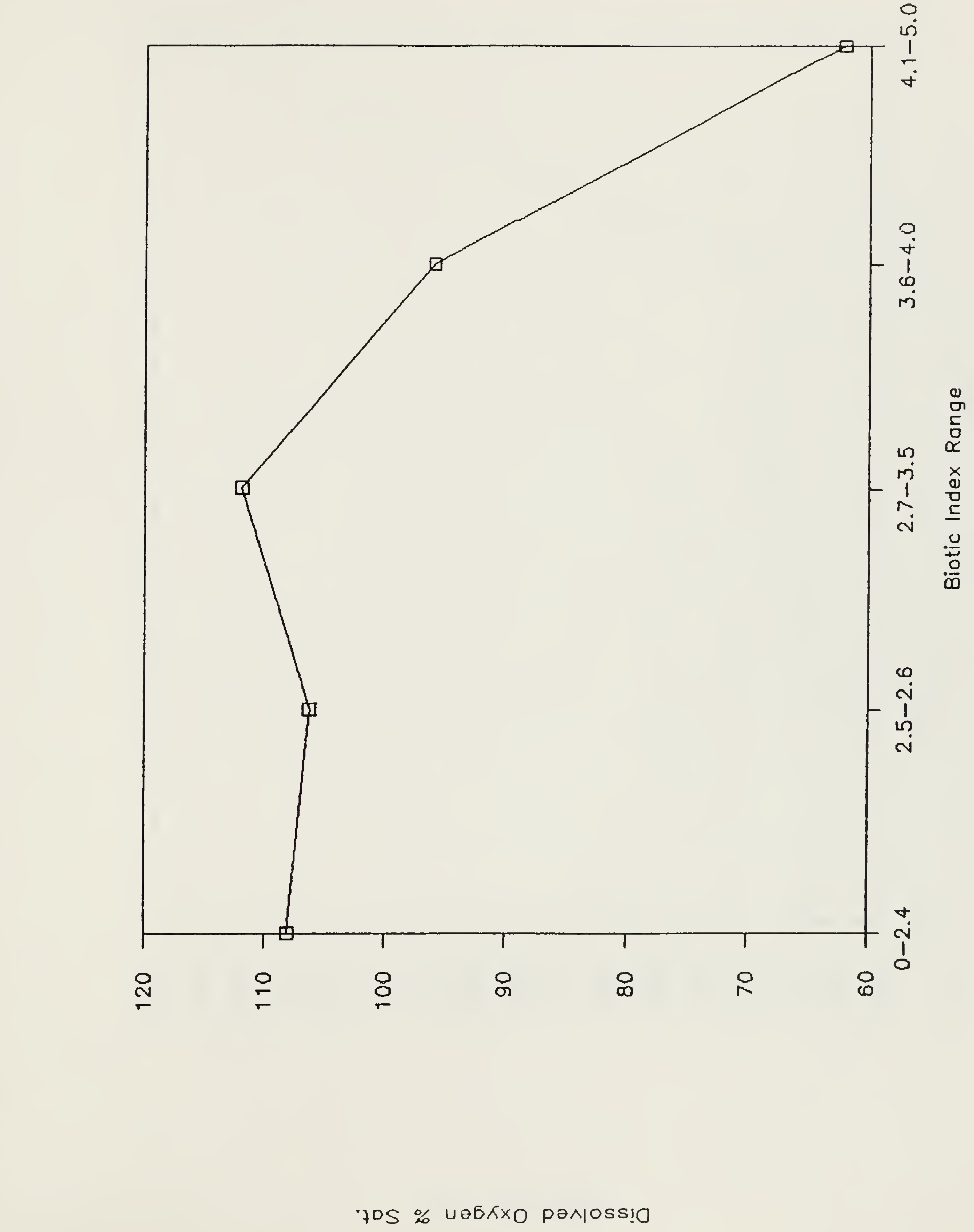
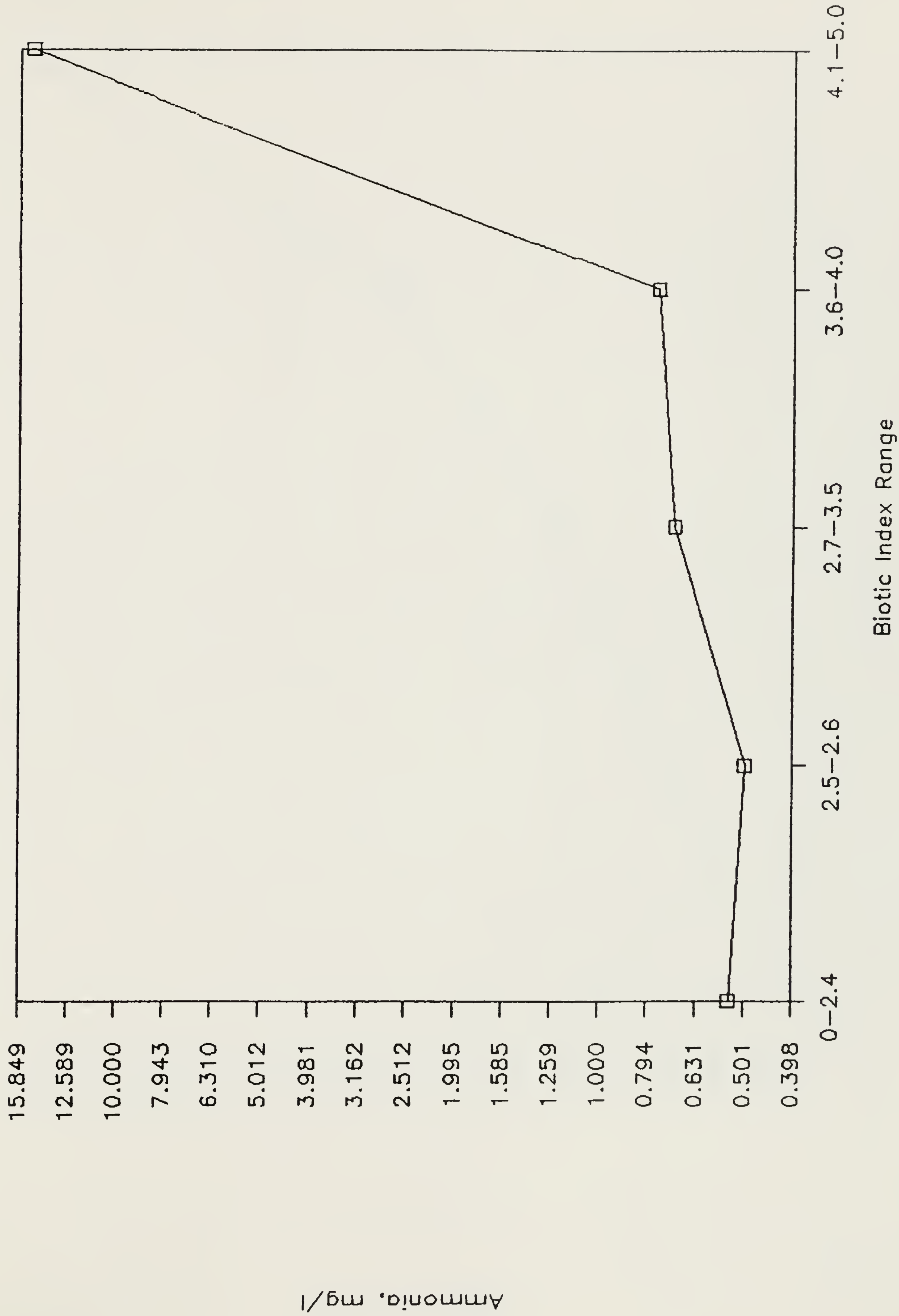

Dissolved Oxygen % Sat.
120
110
100
90
80
70
60
Biotic Index Range
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0

Figure 4c



Ammonia, mg/l
15.849
12.589
10.000
7.943
6.310
5.012
3.981
3.162
2.512
1.995
1.585
1.259
1.000
0.794
0.631
0.501
0.398
Biotic Index Range
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0

Figure 4d

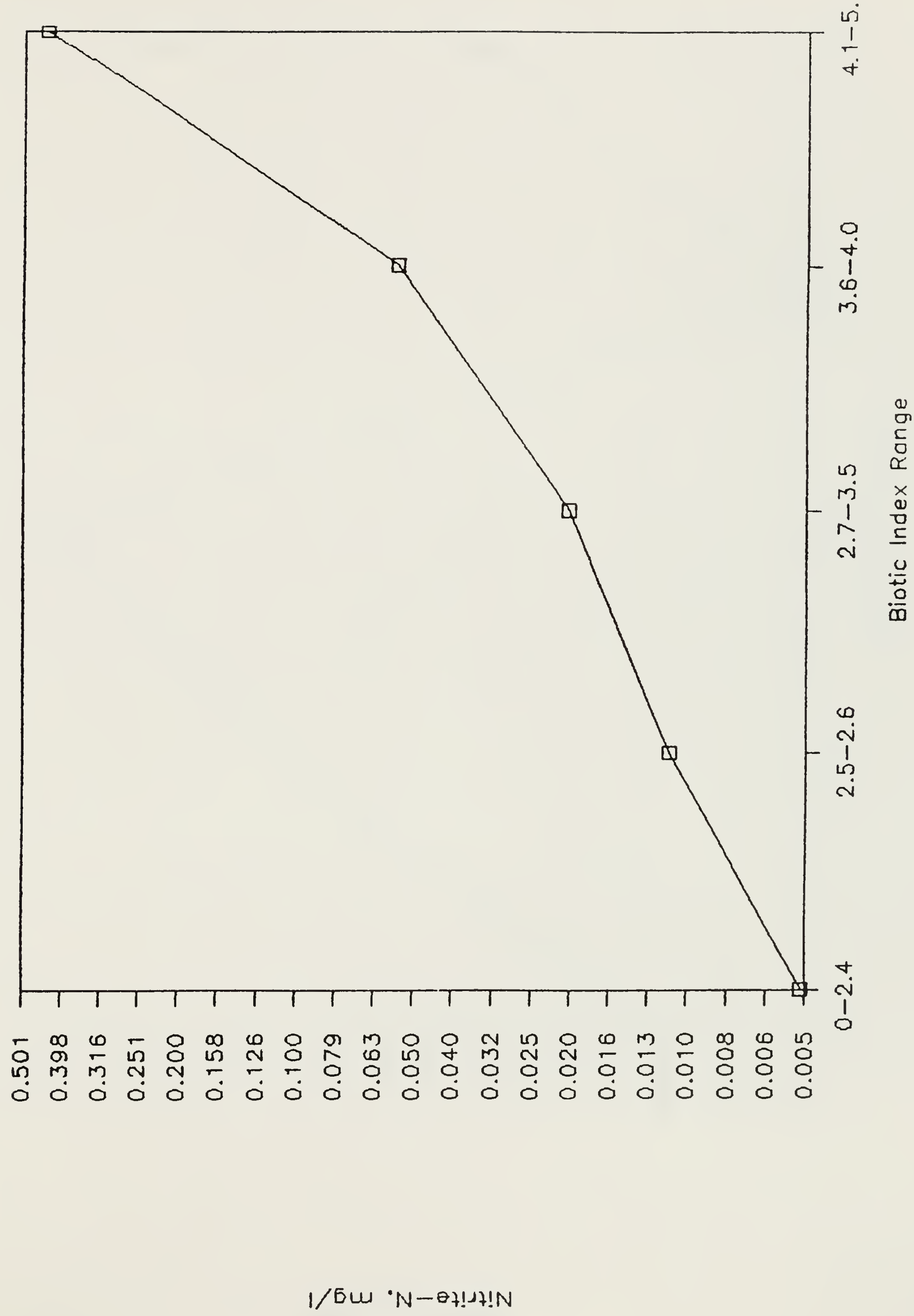
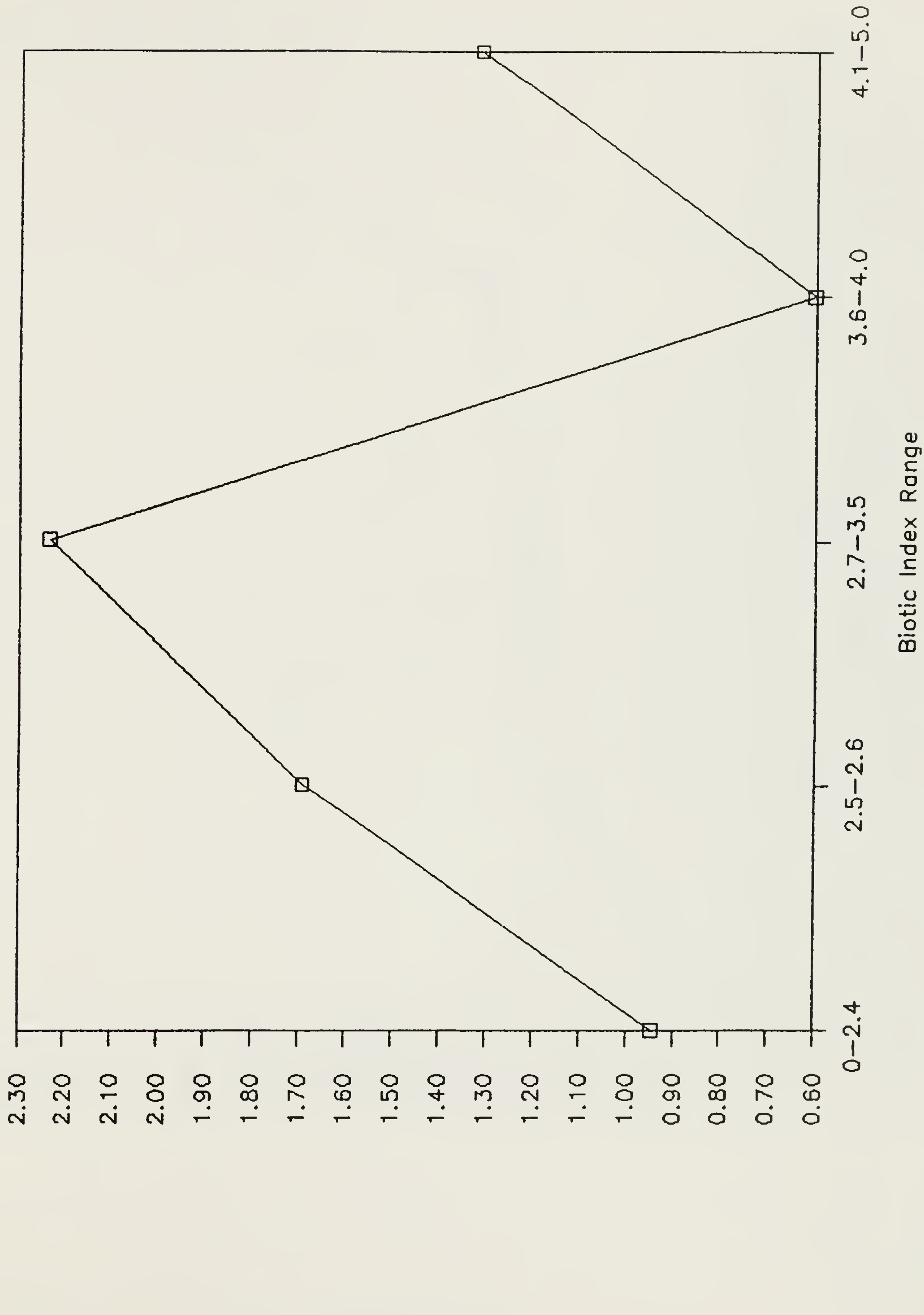

Nitrite-N, mg/l
0.501
0.398
0.316
0.251
0.200
0.158
0.126
0.100
0.079
0.063
0.050
0.040
0.032
0.025
0.020
0.016
0.013
0.010
0.008
0.006
0.005
Biotic Index Range
0-2.4
2.5-2.6
2.7-3.5
3.6-4.0
4.1-5.0

Figure 4e



Nitrate—N, mg/l
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0—2.4
2.5—2.6
2.7—3.5
3.6—4.0
4.1—5.0
Biotic Index Range

Figure 4f

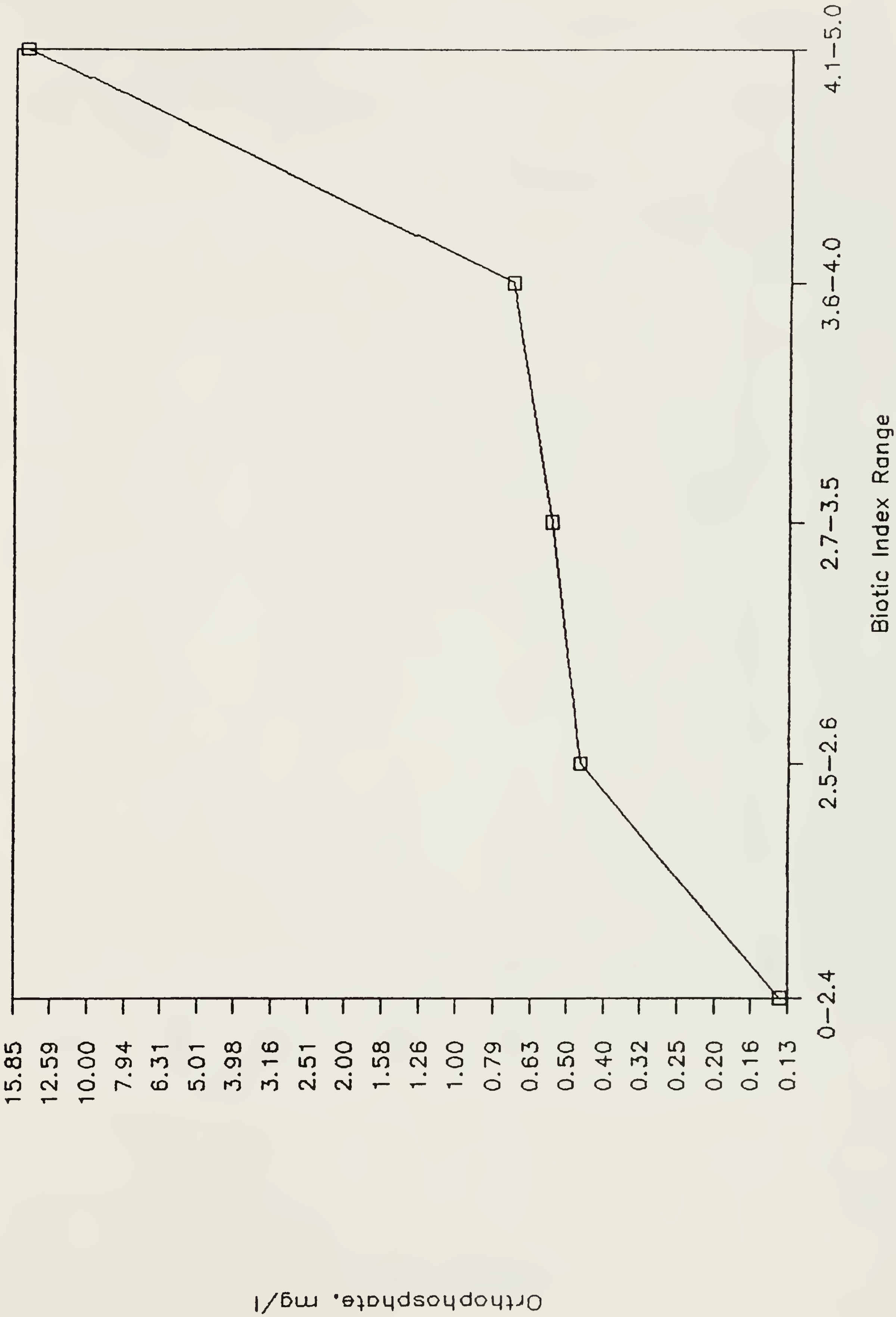

Orthophosphate, mg/l
15.85
12.59
10.00
7.94
6.31
5.01
3.98
3.16
2.51
2.00
1.58
1.26
1.00
0.79
0.63
0.50
0.40
0.32
0.25
0.20
0.16
0.13
Biotic Index Range
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0

Figure 4g

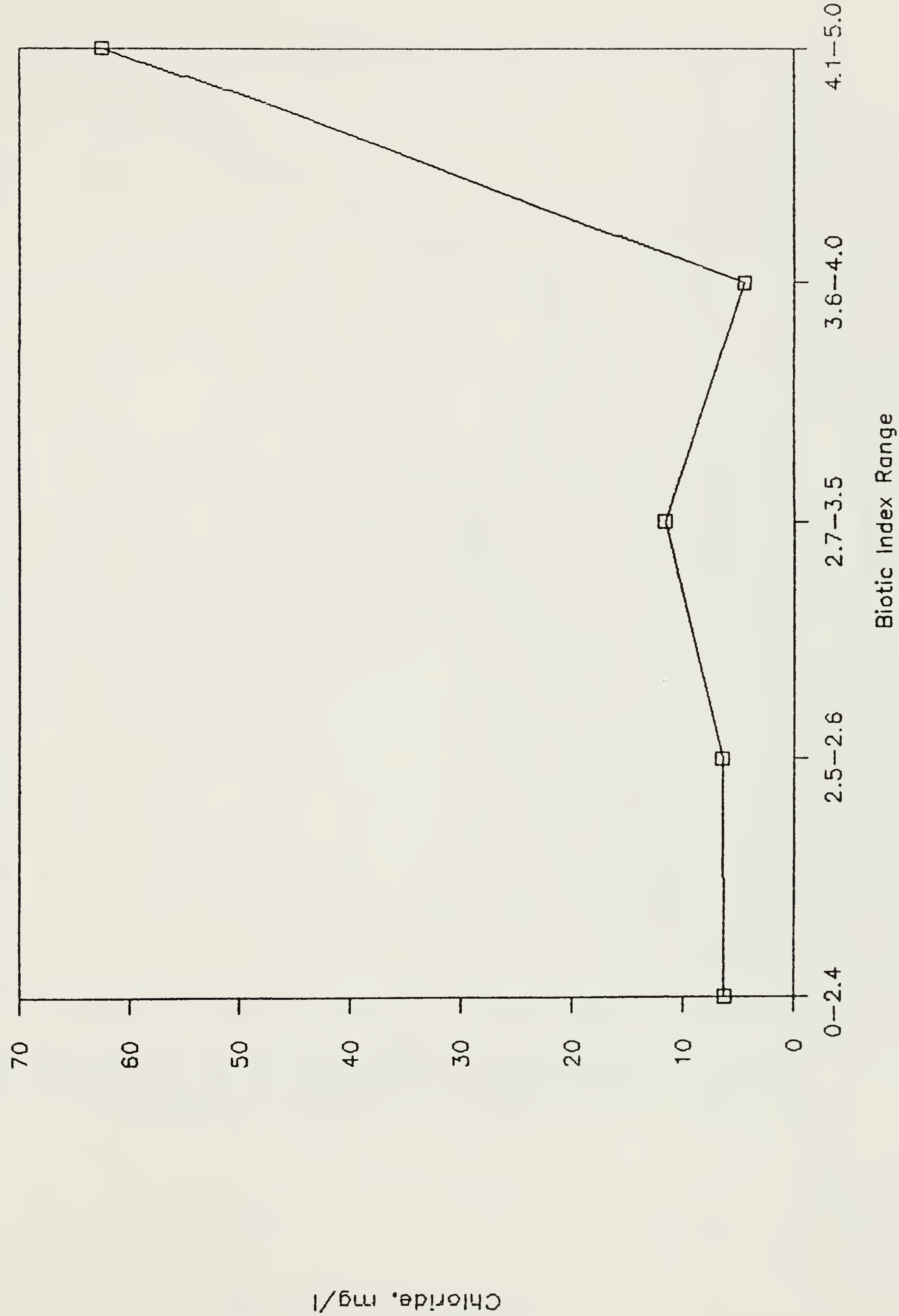
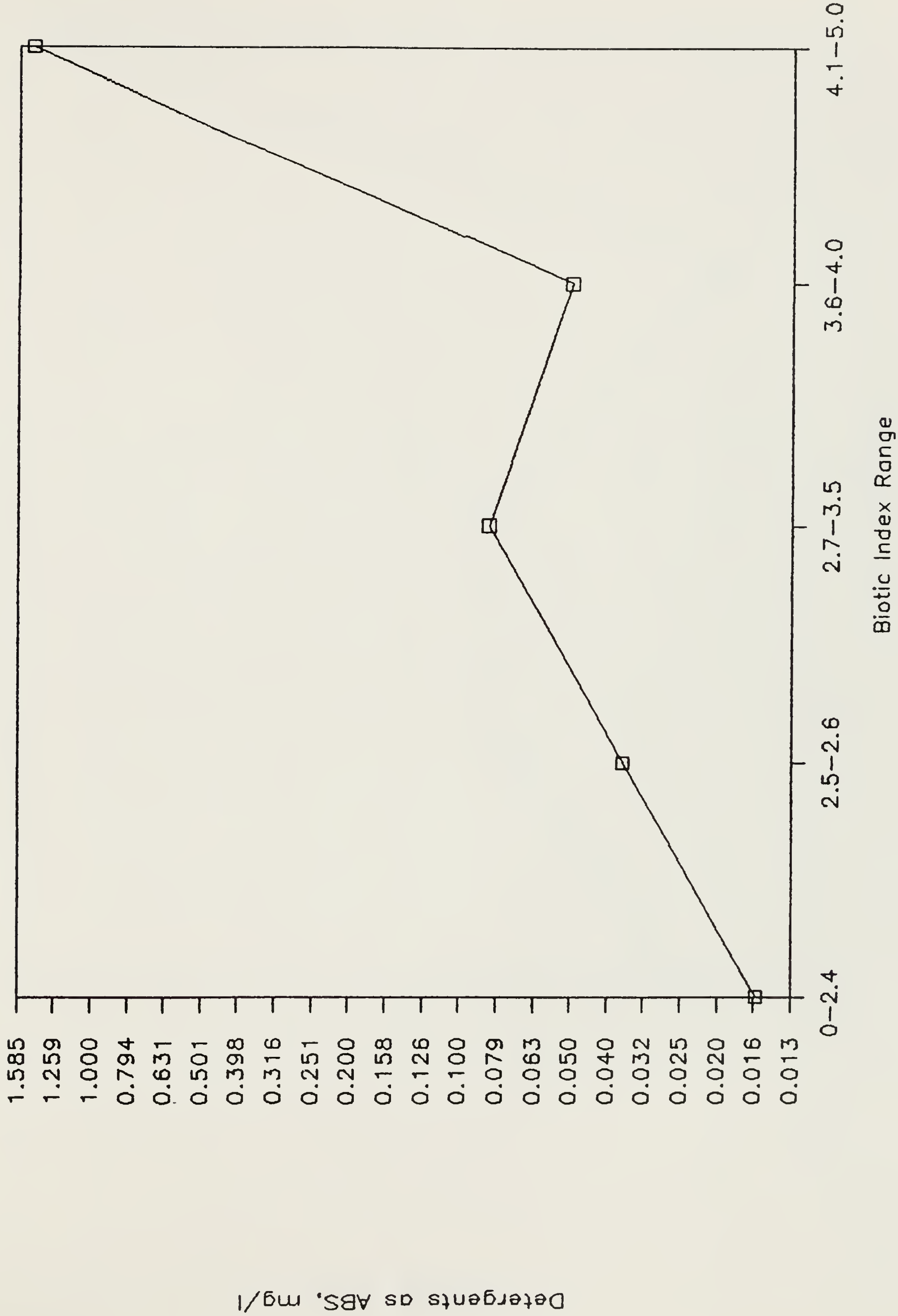

Chloride, mg/l
70
60
50
40
30
20
10
0
0—2.4
2.5—2.6
2.7—3.5
3.6—4.0
4.1—5.0
Biotic Index Range

Figure 4h



Detergents as ABS, mg/l
1.585
1.259
1.000
0.794
0.631
0.501
0.398
0.316
0.251
0.200
0.158
0.126
0.100
0.079
0.063
0.050
0.040
0.032
0.025
0.020
0.016
0.013
Biotic Index Range
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0

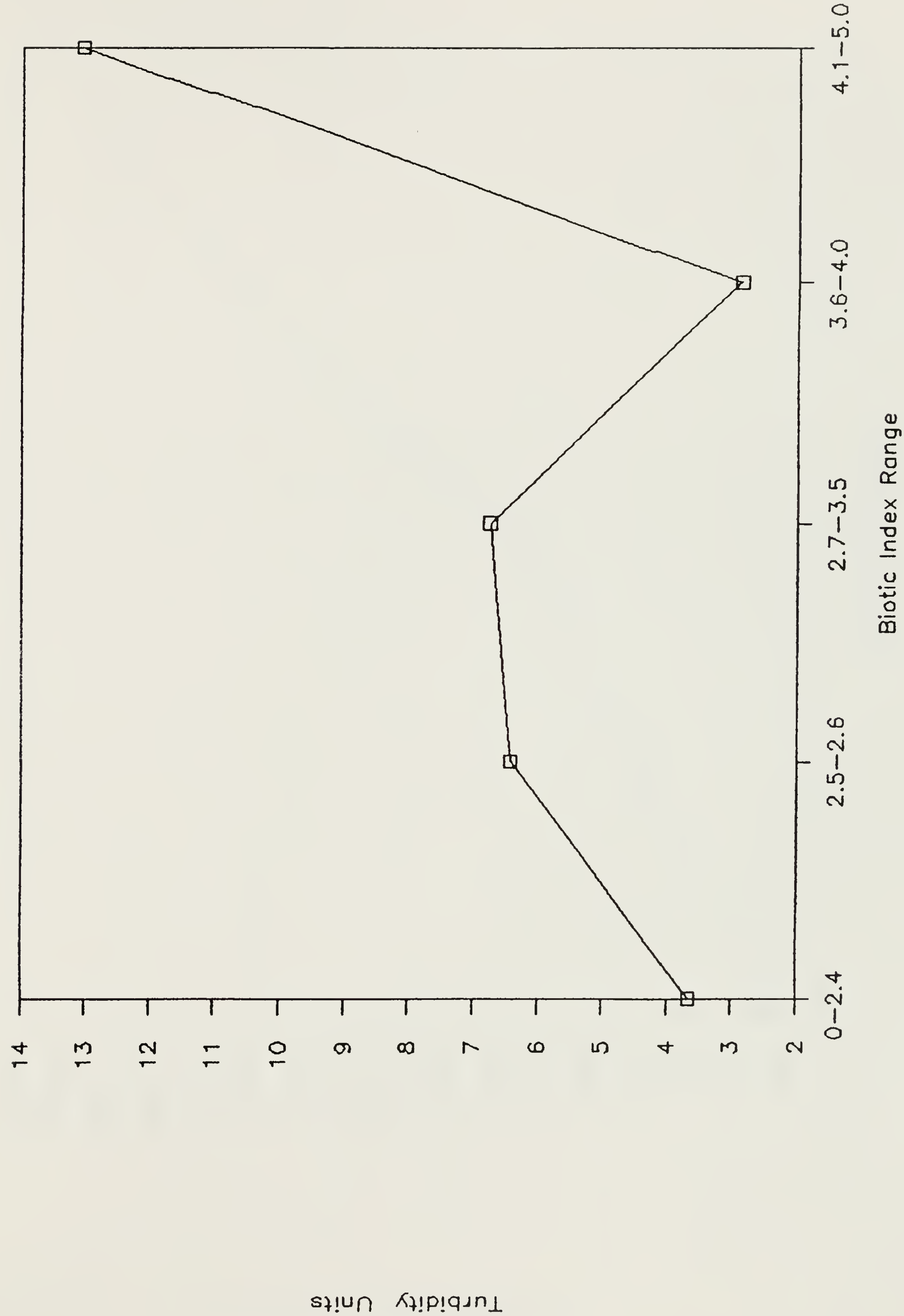
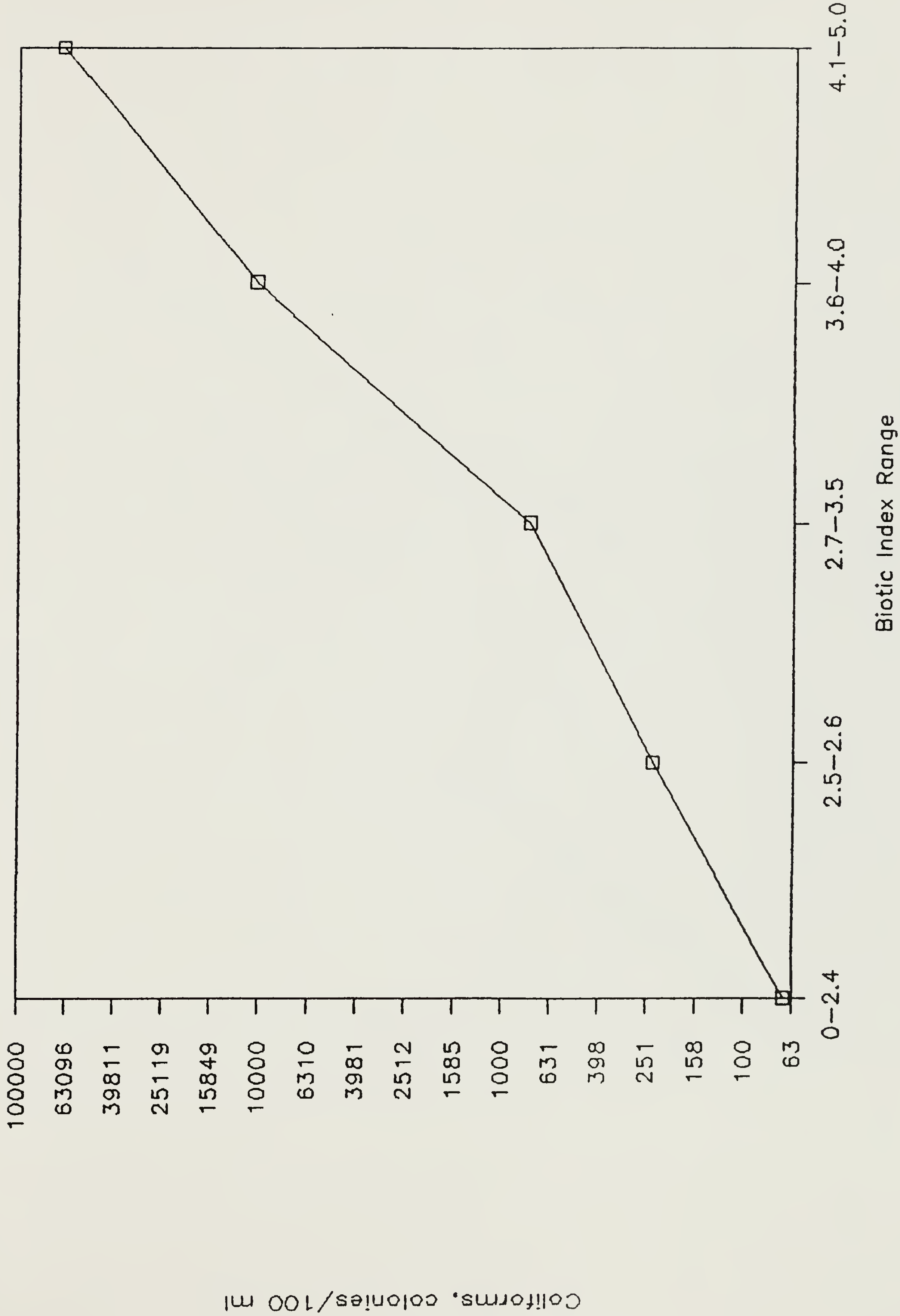
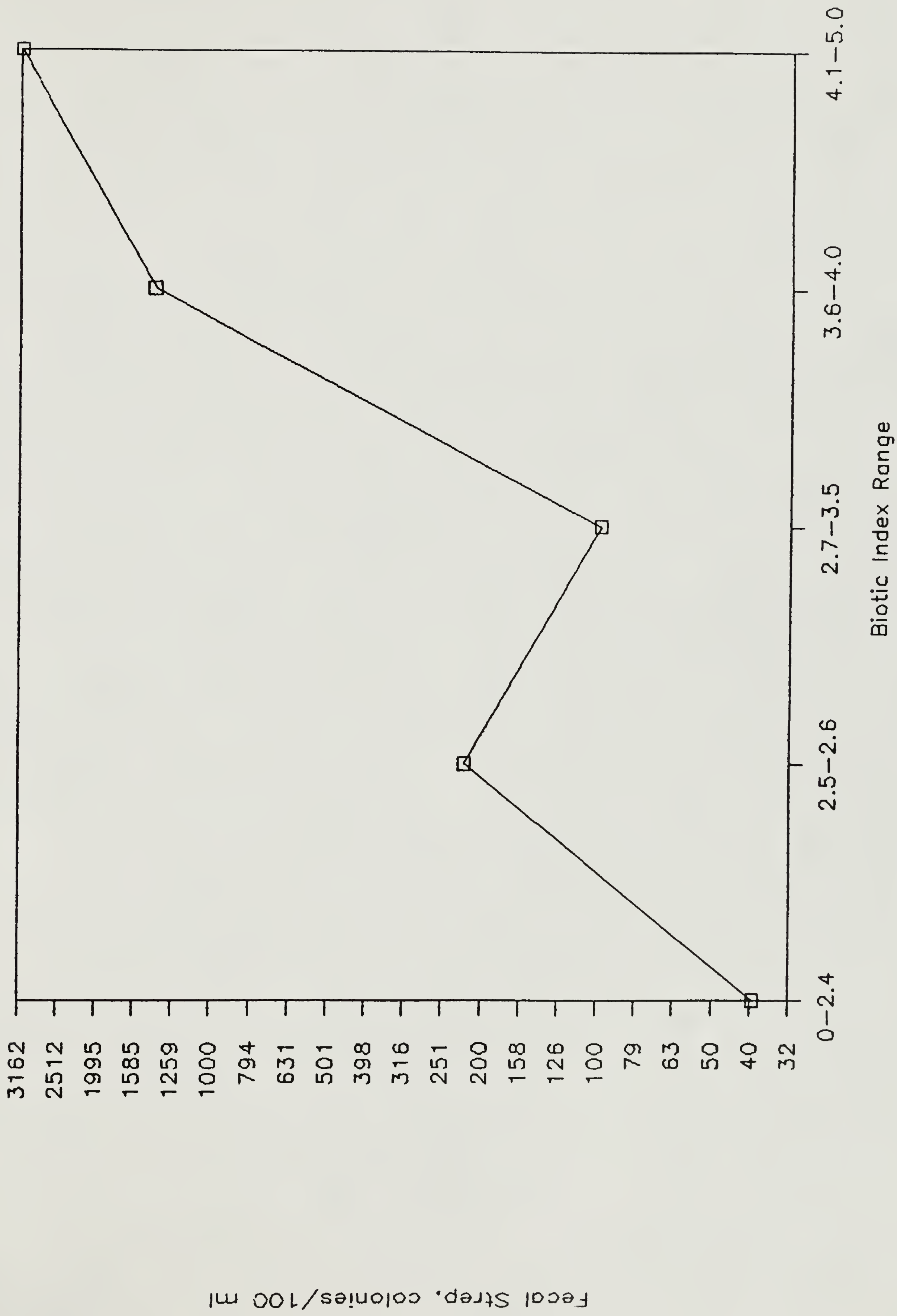

Turbidity Units
14
13
12
11
10
9
8
7
6
5
4
3
2
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0
Biotic Index Range

Figure 4j



Coliforms, colonies/100 ml
100000
63096
39811
25119
15849
10000
6310
3981
2512
1585
1000
631
398
251
158
100
63
Biotic Index Range
0—2.4
2.5—2.6
2.7—3.5
3.6—4.0
4.1—5.0

Figure 4k


Fecal Strep, colonies/100 ml
3162
2512
1995
1585
1259
1000
794
631
501
398
316
251
200
158
126
100
79
63
50
40
32
Biotic Index Range
0–2.4
2.5–2.6
2.7–3.5
3.6–4.0
4.1–5.0